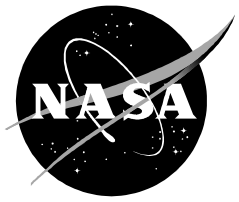

National Aeronautics and
Space Administration

The NASA Scientific Data Purchase Final Report

John C. Stennis Space Center, Mississippi

National Aeronautics and
Space Administration

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Foreword

In 1997, NASA initiated an innovative project called the Scientific Data Purchase (SDP). This experimental project resulted from a Congressional appropriation to investigate the utility of commercial remote sensing data for Earth science research. The project is now complete and a summary of activities and relevance to NASA Earth science research and applications is presented here. This experimental SDP project has demonstrated that NASA can successfully implement a data purchase activity and that industry is willing to respond. In addition, the several examples included in this report indicate the utility of the commercial data and its impact to NASA Earth science research. This report is intended to provide useful information for government agencies considering future data purchases, including those civil agencies responsible for implementing the President's 2003 Commercial Remote Sensing Space Policy.

The SDP was designed to provide NASA's Earth science researchers with a commercial source of observations in addition to the suite of NASA-sponsored missions. As illustrated in the figure below (**Figure 1**), the spatial information cycle indicates the need for both public and private sources of Earth science observations and data products. In other words, researchers should be able to use data streams from both government missions *and* commercial systems to accomplish Earth science objectives. Therefore, an implicit objective of the SDP was to scientifically qualify a subset of commercially available products to meet specific needs of the Earth science community—products that were not available to them through NASA assets (e.g., high spatial resolution visible and near infrared imagery and Interferometric Synthetic Aperture Radar (IFSAR)). This effort has resulted in a process through which other sensors and Earth science products might become scientifically qualified in the future.

The relevance of the SDP and its results are reflected by its importance to NASA and U.S. Government sponsored research programs. For example, the U.S. Climate Change Science Program (CCSP) recognizes the importance of the "human dimension" in science research. To fully understand this concept, there will be requirements for observations of a certain applicable spatial resolution. In many cases, this requirement can be satisfied only with imagery from commercial high resolution sensors. Also, the Solid Earth Science Working Group (SESWG), in support of research in volcanoes, earthquakes, etc., has identified measuring subtle movements of the Earth's crust as early indicators of hazardous events such as land slides, earthquakes, and volcanoes. Many of the observations for this community require high spatial and temporal resolution LIDAR and IFSAR technologies. At present, the commercial industry is the primary source for these types of data from aircraft. Other Federal research programs (e.g., U.S. Weather Research Program, Climate Change Technology Program) are also candidates for the use of commercially available, scientifically qualified Earth science products. Ultimately, the results of the SDP could potentially have far-reaching effects on how the U.S. Government conducts its Earth system science research in the future.

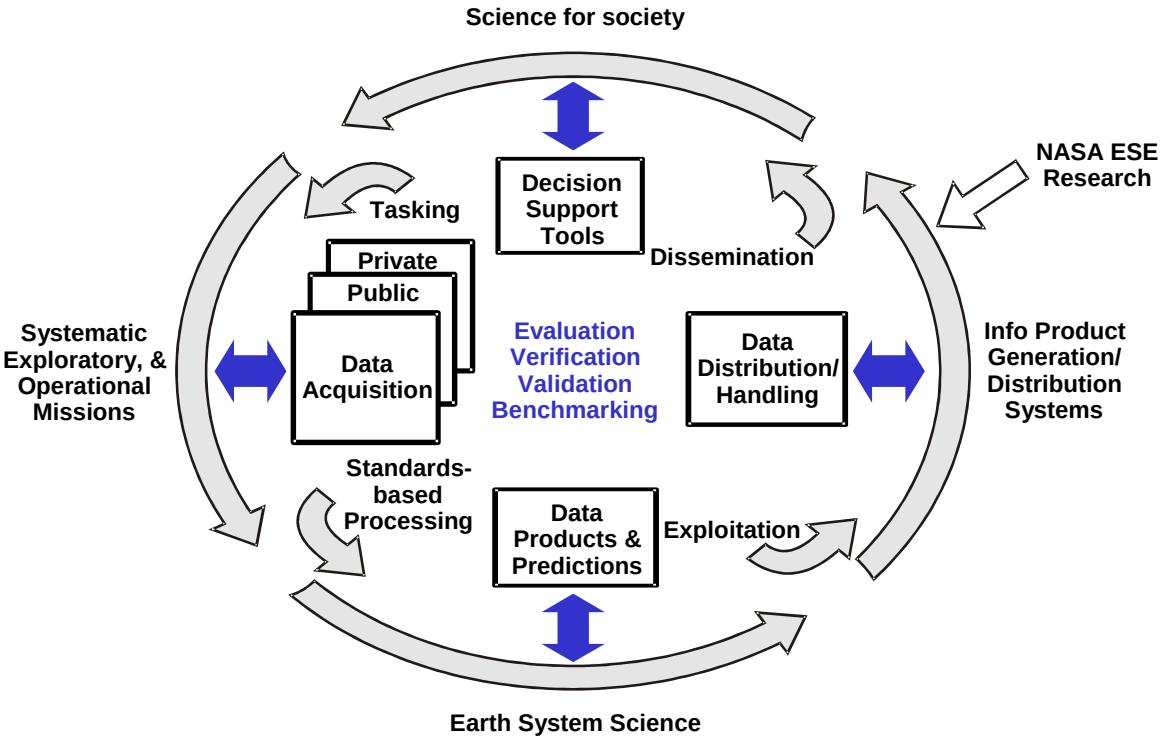


Figure 1. Spatial information cycle.

Executive Summary

This report summarizes the results of the NASA Scientific Data Purchase (SDP) program implemented by the Stennis Space Center Earth Science Application Directorate in fiscal years 1998–2002.

The SDP was conducted in support of NASA's Mission to Planet Earth (MTPE) program (currently known as NASA's Earth Science Enterprise). This Earth Science Enterprise (ESE) provides major observational capabilities for NASA's Earth system science research and for the U.S. Global Change Research Program. Observations supported through the SDP were selected based upon their application to the five science themes of the MTPE/ESE:

- Land-cover and land-use change research
- Seasonal-to-interannual climate variability and prediction
- Natural hazards research and applications
- Long-term climate: Natural variability and change research
- Atmospheric ozone research

The MTPE/ESE science themes, although they have evolved over time, are driven by a set of key science questions that help focus the research program on characterizing the Earth system. More details on these questions may be obtained by reading the NASA ESE Research Strategy for 2000–2010 (NASA, 2000).

The NASA Scientific Data Purchase program began in 1997 as the result of a $50 million Congressional appropriation intended to establish a series of demonstration projects for evaluating the utility of commercial remote sensing data (National Research Council, 2002b). The goals of the program were to assess the use of commercially available remote sensing data for scientific purposes and to gage the willingness of industry to accept a major portion of the up-front financial responsibility associated with routinely providing remotely sensed data products in a cost-effective and timely manner (**Appendix A**). NASA developed a two-phased approach for the implementation of the Scientific Data Purchase program. This two-phased approach made it possible to evaluate the science value of proposed data (Phase I) before committing to additional multi-year data purchases later (Phase II), thus minimizing the risk to the government. In September 1998, NASA selected five commercial vendors to provide high quality remotely sensed data products to a broad segment of the NASA Earth science community. NASA Stennis Space Center (SSC) was assigned the management responsibility for implementing the SDP.

The SDP demonstrated that the commercial remote sensing industry, although still maturing, could provide the Earth science community with some unique, useful, and valuable products. These products included a variety of data types generally not available to NASA Earth science researchers: very high spatial resolution IKONOS satellite imagery acquired from Space Imaging, LLC.; airborne multispectral imagery from Positive Systems, Inc.; high-accuracy digital elevation model and radar imagery from DigitalGlobe (then EarthWatch, Inc.) through Intermap Technologies, Inc., STAR-3*i* Interferometric Synthetic Aperture Radar; and the first-ever global database of orthorectified Landsat imagery from Earth Satellite Corporation (EarthSat). A summary of these data products is listed in Error! Reference source not found.**.** The remaining SDP vendor, AstroVision, Inc., was selected to provide full-disk images of the Earth for global monitoring and natural hazards event viewing upon the launch of its geostationary-orbiting system. Unfortunately, AstroVision was not able to develop and launch its system prior to the

end of its SDP contract, and this contract was subsequently allowed to expire with no financial cost incurred to NASA.

NASA Earth science researchers requested SDP data by submitting tasking requests via the SDP Web site (NASA, 2003b). The requests, similar to research proposals, included a detailed description of how SDP data would be used to support ongoing NASA Earth science research and applications. A NASA Headquarters tasking review committee ensured that SDP data was used to support a wide variety of science research and application areas. The largest portions of data requested through task requests were in support of land cover/land use studies, Earth Observing System (EOS) science validation, and resource management applications. Commercial data acquired through the SDP has greatly benefited several NASA research and applications projects. These projects span a variety of NASA sponsored research and applications studies. A few of the high-impact results include the following:

- Researchers at the University of South Carolina demonstrated how EarthSat GeoCover Landsat orthorectified data could be used to support the U.S. Government Geographic Information for Sustainable Development initiatives through coastal management studies in Tanzania/Kenya. The results of this study were incorporated into a National Academy of Sciences report (National Research Council, 2002a) that was presented at the World Summit on Sustainable Development in September 2002, citing the significance of the EarthSat dataset as the only relatively high spatial resolution global orthorectified dataset available to most developing countries for use in sustainable development projects.
- Space Imaging's IKONOS imagery was used to support studies of sensitive island landscapes and quantifying their responses to changing global conditions, including coastline change, volcanic effects, island subsidence and sea level effects, and effects of ice accumulations. IKONOS imagery provided a mechanism to develop response models that can be extended to more complex regions. An exciting outcome of these studies has been the use of the high spatial resolution imagery as "training" data for remote sensing observations and prospective studies of Mars. The use of SDP high resolution imagery has influenced NASA's decision to implement a sub-meter imaging system on the Mars Reconnaissance Orbiter, which is scheduled for launch in 2005.
- NASA Langley Research Center scientists used DigitalGlobe/Intermap STAR-3*i* digital elevation data and Space Imaging IKONOS imagery to support improved aviation safety in Alaska. The SDP data, combined with aircraft attitude and position information, were used to generate Synthetic Vision System cockpit displays: accurate heads-down views of the mountainous Alaska terrain. These 3-D simulated window views of the terrain demonstrate how remotely sensed imagery can be used to improve pilot situational awareness during poor visibility conditions.
- The Moderate Resolution Imaging Spectroradiometer (MODIS) Land Validation Team employed Space Imaging's IKONOS imagery for validation of MODIS land products. The high-resolution spaceborne imagery served several purposes, including co-registration of other remotely sensed data, design of field sampling strategies, investigation of Landsat 7 Enhanced Thematic Mapper Plus sub-pixel heterogeneities, and spatial variability studies.

Through NASA's SDP, affiliated research scientists have produced 320 publications, including peer-reviewed journal articles, conference presentations, and Web articles. To date, of the studies described in these publications, 34 utilized EarthSat data, 13 utilized DigitalGlobe data, 24 utilized Positive Systems data, and 273 utilized Space Imaging data. A list of these cited references is provided in **Appendix D.** Issues regarding the amount of time it took to receive the SDP data (the time from data acquisition to data receipt) and data rights restrictions were the main problems expressed by a small percentage of the SDP researchers.

The SDP has resulted in several lessons learned. Several of the most significant follow:

- NASA, with limited risk, can procure commercial data that is useful to Earth Science Enterprise affiliated research scientists, and industry is willing to accept the up-front financial responsibility associated with a data purchase program where commercial markets exists beyond NASA requirements.
- NASA has gained an increased understanding of the maturing remote sensing industry and of how the industry and government should approach the many complex issues surrounding commercial imagery purchases (National Research Council, 2002b).
- Proper independent characterization of commercial data is essential for the science community and is important to the applications community. Partnerships with other agencies can contribute to the success of government characterization efforts.
- The centralization of SDP contract, tasking, and data management activities in one location (Stennis Space Center) increased the efficiency of the SDP program and contributed to the effectiveness of verification and validation activities.
- Issues related to export control, data licensing, data archiving, and contract definition are all critical to successful data purchase partnerships and must be addressed at the earliest steps of negotiation.

The SDP has been described as a valuable model, among only a few in the U.S. government, for making commercial data products available to government users (National Research Council, 2002b). However, several challenges must be addressed to ensure the success of future programs. Data licensing agreements that better serve the needs of long-term research are essential. Additionally, a survey of commercial data offerings combined with a systematic study of NASA's Earth science data needs would be beneficial for future programs. NASA's Suborbital Program is currently planning to work with the private sector to understand commercial offerings and to discuss approaches to scientifically qualify commercial assets for NASA research use.

This report was written by SSC's ESA Directorate in support of NASA's Earth Science Enterprise. The ESA Directorate has a history of working with other government agencies, academia, and the private sector to advance remote sensing applications and products and has developed a series of unique public-private partnerships. Over the years, the ESA Directorate has partnered with several operational agencies, colleges and universities, and commercial data providers to collaborate on the development of new products and services that incorporate NASA science and technology results.

The following report includes a background and description of the Scientific Data Purchase Program and its processes, a description of several research activities impacted by SDP data, and a summary of lessons learned during the SDP Program. Additional detailed information is also provided in the appendices. A more thorough, independent review of the SDP program is recommended and should include an assessment of science value and relationship to current NASA Earth science and applications themes, an analysis of existing and planned private-sector capabilities, and an evaluation of the effectiveness of SDP management processes.

1.0 Introduction

The NASA Scientific Data Purchase (SDP) program tested the utility and expanded the use of commercial remote sensing data by the NASA Earth science community. Through the SDP, NASA's Mission to Planet Earth (MTPE) tested a new way of doing business by acquiring remote sensing data products from contracted commercial data providers. In 1998, NASA's MTPE was renamed Earth Science Enterprise (ESE) to reflect the direction of NASA's research into the emerging discipline of Earth system science. (For clarity, since the transition has been made, the rest of this document will refer to ESE rather than to MTPE.) NASA scientists used the commercial data to support ongoing Earth science and applications research.

This document provides (1) an evaluation of the overall effectiveness of the SDP program (to date) and the utility of commercial remote sensing data for Earth science research and applications, (2) a summary of the SDP implementation and lessons learned, and (3) a resource for future government data purchase planning and implementation activities.

2.0 SDP Background

The SDP resulted from a 1997 Congressional mandate directing NASA to allocate $50 million for the purchase of remotely sensed data from commercial sources that could meet NASA's science requirements (U.S. Senate, 1996). This mandate stated specifically that NASA should purchase commercial data "where feasible and cost-effective" if these data sources "fully satisfy the scientific requirements of NASA."

Aware of the impending Congressional directive, NASA researched the available and planned commercial industry data products through the release of a Request for Information (RFI) in May 1996. The purpose of the RFI was to determine if the commercial sector could supply Earth observation data suitable to support NASA's basic and applied research in Earth System Science. The RFI also explored the willingness of industry to accept a major portion of the upfront financial responsibility in system development as a new way of doing business with the government. The RFI requested information from commercial entities on data sources to support the current Earth Science Enterprise (ESE) science research theme areas. Using the information provided by the RFI, NASA developed a two-phased approach for the implementation of the Scientific Data Purchase program. A two-phased approach made it possible to evaluate the critical characteristics and value of proposed data (Phase I) before actually committing to additional specific data purchases (Phase II), thus minimizing the risk to the government.

On May 23, 1997, NASA Request for Offer (RFO) No.13-SSC-O-97-21 (provided in **Appendix A**) solicited proposals for Phase I of the Earth Science Enterprise Scientific Data Purchase program. The RFO called for remotely sensed datasets that would provide new science measurements and/or more cost-effective ways of performing ESE research. Respondents were asked to provide information on data products, price, data validation, data licensing, and applicability to the then current ESE science research themes:

1. Land-Cover and Land-Use Change Research

2. Seasonal-to-Interannual Climate Variability and Prediction

3. Natural Hazards Research and Applications

4. Long-Term Climate: Natural Variability and Change Research

5. Atmospheric Ozone Research

The release of the RFO and management and responsibility for implementing the SDP program was assigned to NASA's Earth Science Applications (ESA) Directorate (then known as the Commercial Remote Sensing Program) at Stennis Space Center (SSC).

Eighteen companies submitted Phase I proposals offering 65 different prototypical products consisting of both actual and simulated data. The proposals covered a wide variety of sensor types, data types, resolutions, physical parameters, and processing levels. Phase I proposals were evaluated by both science and business teams. Evaluation criteria included best value characteristics, such as business and pricing factors, science relevance, and past performance (**Appendix A**). In December 1997, 10 contracts were awarded for 22 Phase I products.

2.1 Phase I Activities

During Phase I, the 10 contractors acquired, developed, or simulated prototypical datasets and delivered them to NASA. A total of $3.9 million was allocated to Phase I contracts and support activities. The goal of Phase I was to evaluate the prototypical datasets to select products for purchase and use in Phase II of the SDP. Selection of datasets for Phase II was based on an assessment of scientific value, technical risk, and business risk. An independent science assessment was conducted to determine the scientific value for each Phase I data product. Under the oversight of ESE Science Theme Managers, five science teams (representing each theme area) composed of academic and government research scientists were assembled. Early in Phase I, the Science Assessment Teams formed working groups pertaining to their area of expertise and established metrics, viewed data samples, reviewed proposals, discussed data distribution and data licensing, examined science needs, and evaluated Phase I products. The scientists assessed each data product separately, considering contribution to science themes, global change research, and ESE goals.

Engineers and scientists in the ESA Directorate at SSC conducted independent verification and validation (V&V) of the Phase I data. The objective was to provide the Phase I Science Assessment Teams with information on data quality based on an independent review. Verification included a check of key data specifications, such as cloud cover, frame overlap, and metadata to ensure that the terms of the Phase I contract were fulfilled. To support the science assessment, information on the full product-generation process was collected, including documentation on the sensor, the mission, ground instruments, data collection methods, image processing, references, and company test results. Phase I validation of system performance included a review of laboratory calibration reports and an analysis of operational performance on spatial, spectral, geopositional, and radiometric accuracies. Image products were validated for vertical and horizontal coordinate accuracy and for classification accuracy. In some cases, simulation or production algorithms were also examined.

The Science Assessment Teams reviewed the results of SSC data validation, heard presentations from the data vendors, examined aspects of the data, and formed a consensus on Phase II science recommendations. The teams provided recommendations to NASA regarding data purchase conditions,

limitations, concerns, enhancements, geographic coverage, revisit times, and prioritization (Goward et al., 1998).

The Science Assessment Teams' recommendations, along with technical and business risk, were assessed, and Phase II award recommendations were presented to the NASA ESE Associate Administrator, who served as selecting official. At the close of fiscal year 1998, five companies were awarded Phase II data purchase contracts: AstroVision International, Inc.; Earth Satellite Corporation; EarthWatch, Inc.; Positive Systems, Inc.; and Space Imaging, LLC.

2.2 Phase II Activities

The objective of Phase II of the SDP was to provide data to NASA's affiliated researchers to support ongoing Earth science research and applications. Four Phase II data providers were awarded three-year indefinite delivery indefinite quantity (IDIQ) contracts beginning in September 1998; one data provider was awarded a firm-fixed-price contract for a fixed number of products. The IDIQ contract mechanism allowed NASA to purchase a minimum amount of data from each provider, with the option of purchasing additional data, up to a maximum amount. This allows data to be purchased as needed through task orders issued to the contractor. During Phase II, approximately 7.5 terabytes of distributable data were purchased from four of the five data provider companies. A summary of products purchased during Phase II is shown in **Table 1**

Stennis Space Center's ESA Directorate administered the Phase II contracts. SDP Phase II administration includes processing of science data requests, interaction with the Phase II companies, delivery verification, data characterization, and data distribution. A total of $4.2 million was allocated to the SDP administration and independent data characterization activities.

Table 1. Overview of NASA Scientific Data Purchase products.

Data Provider	Image Data Product	Sensor	Data Type	Pixel Size	Horizontal Positional Accuracy	Quantization	Radiometric Accuracy	Maximum Acceptable Cloud %
EarthSat	Orthorectified MSS	Landsat MSS	MSS	57 m	±100 m	8 bits	NA	<20%
	Orthorectified TM	Landsat TM	TM	28.5 m	±50 m	8 bits	NA	<20%
	Orthorectified TM Mosaics	Landsat TM	TM	28.5 m	±50 m	8 bits	NA	<20%
EarthWatch	Orthorectified Image Maps	STAR-3*i* IFSAR	X-Band SAR	2.5 m	±2.5 m	8 bits	NA	N/A
	Digital Elevation Models	STAR-3*i* IFSAR	X-Band SAR	10 m	±2.5 m	8 bits	NA	N/A
Positive Systems	IM-R1I-55 – Corrected Orthorectified Imagery	ADAR 5500	MS	0.7 m	±100 m (center pt)	8 bits	± 10% Abs ± 5% Rel	<10%
	MOS-G1 – Geo-Mosaic	ADAR 5500	MS	0.7 m	±12.2 m (benign) to ±50 m (extreme relief)	8 bits	NA	<10%
Space Imaging	Original Pan	IKONOS	Pan	1 m	±250 m (std) ±3 m (precision)	11 bits	±10% Abs ±5% Rel	<10%
	Original MS	IKONOS	MS	4 m	±250 m (std) ±5 m (precision)	11 bits	±10% Abs ±5% Rel	<10%
	Master (Orthorectified) Pan	IKONOS	Pan	1 m	±12.2 m (std) ±2 m (precision)	11 bits	±10% Abs ±5% Rel	<10%
	Master (Orthorectified) MS	IKONOS	MS	4 m	±12.2 m (std) ±5 m (precision)	11 bits	±10% Abs ±5% Rel	<10%
	Stereo Pair	IKONOS	Pan	1 m	±25.4 m	11 bits	NA	NA
	Stereo Pair	IKONOS	MS	4 m	±25.4 m	11 bits	NA	NA
	Model DEM, Level D	IKONOS	NA	15 m	±25.4 m	NA	NA	NA

MS – Multispectral
Pan – Panchromatic

2.2.1 Products and Licensing

2.2.1.1 Earth Satellite Corporation

The Earth Satellite Corporation (EarthSat), located in Rockville, Maryland, was awarded a $16.4 million contract to deliver orthorectified Landsat imagery covering global land areas for two historical time frames. The first time frame contains some of the earliest images of Earth taken from space: Multispectral Scanner (MSS) imagery collected during the mid-1970s,. The second contains Thematic Mapper (TM) imagery collected during the late 1980s and early 1990s. Both datasets were intended to serve as a baseline for studies of global change. EarthSat achieved global coverage by acquiring historical imagery from U.S. archives and foreign ground stations. The best available scenes for each Landsat path/row were selected through collaborative evaluation with scientists at NASA's Goddard Space Flight Center. The TM and MSS imagery were orthorectified to an accuracy of ±50 meters root mean square error (RMSE) and ±100 meters RMSE, respectively, using control points from government sources. The company also provided mosaic scenes of the TM coverage.

Science rationale for Phase II purchase of EarthSat products included the following: "A common universal geographic reference framework for Landsat imagery is needed for providing spatial data and image information, since none exists at present. The proposed orthorectified image data set will be the only universally available global data set, unencumbered by licenses or user restrictions" (Goward et al., 1998).

2.2.1.2 DigitalGlobe, Inc.

DigitalGlobe (then known as EarthWatch, Inc.) of Longmont, Colorado, in partnership with Intermap Technologies, Inc., was awarded a $6.2 million SDP Phase II contract to provide radar and elevation data from an airborne Interferometric Synthetic Aperture Radar (IFSAR) system. The STAR-3*i* X-band radar imagery was collected at 2.5-meter resolution and processed into 7.5' quadrangle mosaics. Orthorectified radar image maps have a horizontal accuracy of ±2.5 meters RMSE. Digital elevation model (DEM) products have a horizontal accuracy of ±2.5 meters RMSE and a vertical accuracy ranging from ±1 meter to ±3 meters RMSE. The data is useful for a wide range of applications involving land use, land cover, and terrain modeling.

Phase II science assessment rationale for selection of the STAR-3*i* products included the following comments: "There is a need on a regional basis for 3-meter interferometric X-band SAR data with co-registered 2.5-meter DEM data at a z-accuracy of <3 meters for both regional land use/land cover assessment and hydrologic modeling research. The X-band SAR data are of significant value for obtaining information on canopy surface characteristics, wetlands distribution, and detailed urban structure, especially in cloud-shrouded environments. Optical photogrammetry can provide more accurate DEMs, but not in perennially cloudy areas. Data may also be of significant value during cloud-shrouded disasters" (Goward et al., 1998).

2.2.1.3 Positive Systems, Inc.

A $2.9 million contract was awarded to Positive Systems, Inc., of Whitefish, Montana, to provide 1-meter multispectral imagery, image mosaics, and collateral ground truth data. The imagery was captured with the Airborne Data Acquisition and Registration (ADAR) 5500, an 8-bit sensor with bands similar to the first four Landsat bands. The sensor is capable of producing imagery and mosaics referenced to 1:24,000

scale national map accuracy standards. In addition to providing high-resolution detail on land use and land cover, Positive Systems datasets and products are useful for ground calibration and cross-sensor comparisons.

Comments from the Phase II science assessment team provided the rationale for the Phase II purchase of ADAR 5500 data: “Data would make a major contribution to NASA’s ESE and the U.S. Global Change Research Program. Information provides ‘virtual ground truth’ on land cover spectral properties in the spectral region used to produce spectral vegetation indices, and provides a direct link to the types of field measurements traditionally carried out by field scientists such as ecologists. These detailed aircraft measurements will permit field measurements to be scaled to coarser satellite sensor systems including IKONOS, Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Landsat-7, and Moderate Resolution Imaging Spectrometer [sic] (MODIS). These images will provide the detailed spatial/spectral information needed to comprehensively characterize land cover conditions at EOS intensive study sites” (Goward et al., 1998).

2.2.1.4 Space Imaging, LLC

Space Imaging, LLC, of Thornton, Colorado, provides space-based 1-meter panchromatic and 4-meter multispectral images, image mosaics, and DEMs through an $11.3 million Phase II SDP contract. The IKONOS satellite collects data in visible and near-infrared bands at 11-bit radiometric resolution. Images can be provided at two levels of horizontal geometric accuracy. High spatial resolution, broad coverage (11 x 11 km scene), and the relative stability of a spaceborne platform provides significant potential for efficient land-use/land-cover mapping, as well as validation of coarser resolution systems.

The Phase II science assessment rationale for purchase of IKONOS data is as follows: “The IKONOS satellite data will make a major contribution to NASA’S ESE and the U.S. Global Change Research Program. IKONOS will be able to provide high resolution data that will be extremely valuable when scaling detailed ground observations to coarser resolution systems (Landsat TM and MODIS) and to support field campaigns carried out in support of missions such as EOS. The 1-meter panchromatic and 4-meter multispectral data will be highly complementary to current ESE missions due to its high spatial resolution. IKONOS has the advantage over aircraft-based systems by being able to image any location on the Earth’s surface and to do this repetitively” (Goward et al., 1998).

2.2.1.5 AstroVision, Inc.

AstroVision International, Inc., of Bethesda, Maryland, was awarded a $1.4 million SDP Phase II contract. AstroVision planned to develop and launch a satellite system to provide coarse spatial resolution (~700 km), high temporal resolution full-disk imagery of the Earth from geostationary orbit. Additionally, the sensor system design included a “pointable” capability to provide higher spatial resolution (~600 m) imagery of selected regions. The imagery was intended to support global monitoring and event monitoring of natural hazards, such as tornadoes, hurricanes, and volcanoes.

Unfortunately, AstroVision did not deliver this data to NASA within the timeframe allotted by the SDP contract because of difficulties in completing development of their satellite system. The SDP contract was therefore allowed to expire with no cost incurred to NASA. The $1.4 million associated with this contract was returned to the U.S. Treasury Department.

2.2.1.6 Licensing

Throughout the Phase II contract negotiation process, data licensing and distribution rights provisions were of great interest. Traditionally, NASA scientists and researchers were accustomed to the free and open distribution rights of non-military government-built remote sensing systems. However, free and open distribution rights significantly impacted the cost of commercial data to NASA. Thus, the majority of Phase II contracts included provisions that allowed data to be freely distributed only among NASA-affiliated researchers with the exception of EarthSat data products, which could be freely distributed outside of the NASA community.

2.2.2 Outreach

Early in Phase II, NASA performed customers/constituents outreach to provide the ESE community with information about the SDP program. Outreach included presentations given to NASA Headquarters Code Y program managers, Goddard Space Flight Center Earth Sciences management, House and Senate Congressional Staffers, representatives from the Office of Management and Budget, researchers at the Landsat Science Meeting, the Earth Science Information Partners (ESIP) Working Group Meeting, the Goddard Institute of Space Sciences, the Earth Science Technology Office, and the MODIS Science Meeting. In addition, mass-mailings were sent via e-mail to ESE principal investigators, and an SDP Web site was developed (NASA, 2003b). The Web site also functions as a data tasking, querying, and ordering interface for SDP data.

2.2.3 Tasking and Distribution

The NASA SDP data tasking, ordering, and distribution process is shown in **Figure 2**.

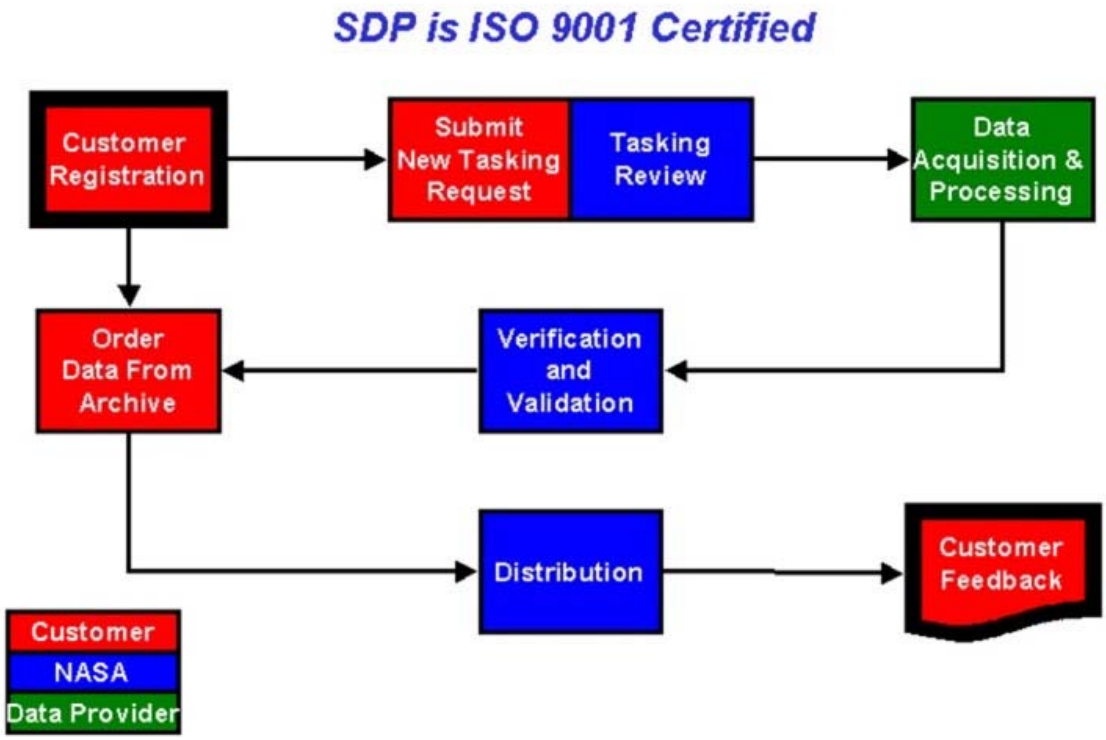


Figure 2. SDP general process flow.

Through the Scientific Data Purchase Web site, NASA's affiliated researchers registered to become users of the SDP by supplying such information as organization, citizenship, and the NASA grant, contract, or agreement on which he/she was working so that SDP personnel could verify the user's ESE affiliation. Once the registration was approved, researchers also used the SDP Web site to submit requests for data acquisition, called a task request. Task requests were reviewed by a Science Tasking Committee composed of NASA Headquarters ESE science and applications program managers who evaluated the requested data's potential contribution to the stated research objectives. After the Science Tasking Committee approved a task request, the requirements for data acquisition were sent to the appropriate data provider, who then acquired the data and delivered it to NASA.

Data received from the data providers was ingested into the SDP data management system. All SDP data products delivered to NASA underwent a thorough order verification and inspection process to ensure that the conditions of the contract and tasking request were met. The details of this process are described in **Figure 3**.

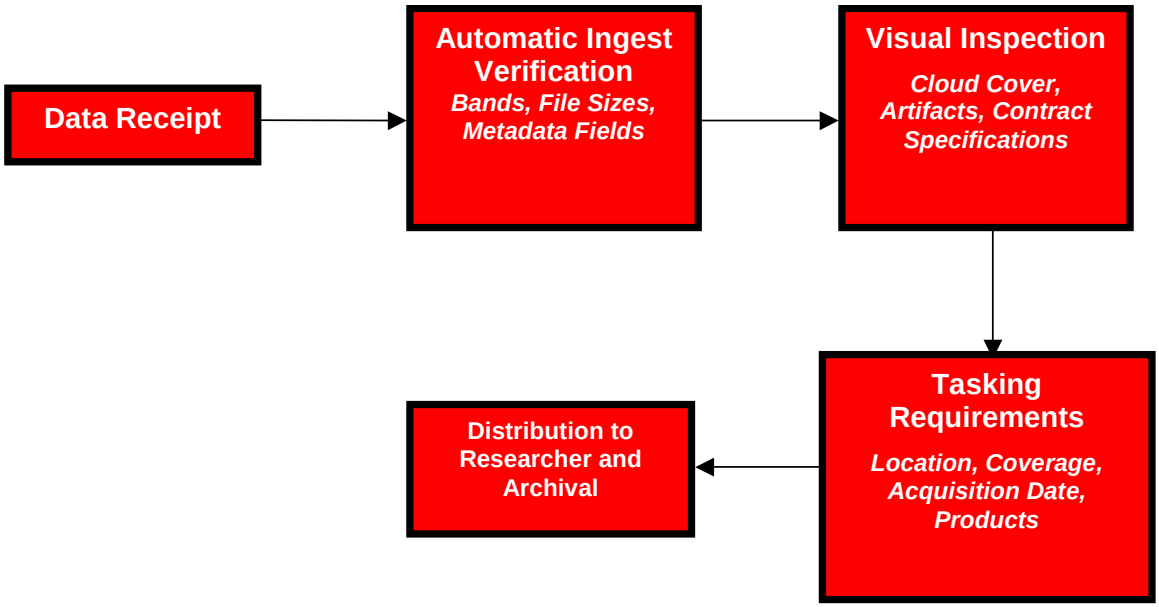


Figure 3. SDP shipment verification process flow.

Once data passed the inspection and shipment verification process, it was duplicated and sent to the researcher. A copy of each dataset became part of the SDP archive and was made available for ordering by other registered SDP users. Additionally, the U.S. Geological Survey (USGS) Earth Resources Observation System (EROS) Data Center (EDC) serves as the long-term archive for EarthSat's Landsat orthorectified products purchased through the SDP. The USGS EDC was provided $3.6 million for the archive and distribution of EarthSat products.

2.2.4 Independent Data Product Characterization

An independent characterization was also performed on selected datasets for each of the Phase II contracts. This process included laboratory characterizations of system performance and in-flight measurement of geopositional accuracy, spatial response, and radiometric accuracy using independent ground-based reference data. The characterization process was performed on selected datasets from each vendor as a way of monitoring the vendor's compliance with contract data specifications and of ensuring data quality for science use. The centralized nature of the SDP program allowed personnel to characterize a representative sample of the datasets against these specifications. Details of the characterization effort are documented in several reports, publications, and workshop proceedings.

The EarthSat TM and MSS orthorectified datasets were assessed for geopositional accuracy using an independent set of government-provided ground control points. The ground control consisted of identifiable features within the ~30-meter TM imagery whose locations were accurately known. The known locations were compared to those defined by the TM imagery to determine if the imagery met the ±50-meter absolute horizontal accuracy specification. The coarser spatial resolution of the MSS orthorectified products did not permit the identification of the same ground control features used for the TM accuracy assessment. Additionally, because EarthSat orthorectified the MSS imagery on a scene-by-scene basis using TM imagery as horizontal control, a scene-by-scene assessment approach for the MSS imagery was identified as more appropriate than the regional assessment used in the TM validation. Thus, to verify the accuracy of the MSS, selected MSS scenes were compared to the corresponding verified TM scene. In this analysis, it was assumed that if a particular TM scene was found to meet the ±50 meter

specification, that scene could serve as “truth” for verification of the corresponding MSS scene for the same area. Thus, the location of an identifiable feature in an MSS scene was compared to the location of the same feature within the TM scene. If the MSS-defined location of the feature was within ±50 meters of the TM-defined location, it was determined that the MSS scene was within the ±100-meter absolute horizontal accuracy specification.

Independent characterization of the DigitalGlobe/Intermap STAR-3*i* products included both a process review and a product evaluation. A site visit to the Intermap facility was conducted by NASA to review data production processes and quality control measures. The processes at both Intermap and DigitalGlobe were registered to the ISO 9000 standard. In addition, the STAR-3*i* system and data had previously undergone independent validation by other government agencies. Intermap performed periodic calibration flights over corner cube reflective targets to maintain system calibration throughout the SDP contract. The results of each calibration were delivered to NASA in the form of a report. NASA reviewed each report to verify horizontal and vertical accuracy for a range of antenna positions based on data from corner reflectors and transects of the calibration test site, as well as spatial resolution from corner reflectors. Additionally NASA performed independent product characterization on delivered STAR-3*i* products. Vertical accuracy of digital elevation models was verified for both flat and mountainous terrain using National Geodetic Survey (NGS) monument data from the National Oceanic and Atmospheric Administration as the reference data. The NGS vertical position was compared with the vertical position for the same locations in the DEMs.

The Positive Systems ADAR 5500 camera underwent laboratory characterization in the NASA ESA sensor laboratory. Measurements of spectral response, dynamic range, linearity, and spatial response were performed in collaboration with Positive Systems personnel. The NASA laboratory characterization resulted in a modification to the sensor’s spectral filters to improve performance and to ensure that the data met contract specifications. Characterizations of the sensor were also performed in flight. The in-flight spatial response was measured by acquiring data over specialized edge targets. Radiometric accuracy was determined through collection of ground reflectance and atmospheric data coincident to the data acquisition. An automated validation capability was also developed and utilized on all Positive Systems datasets. Spectral registration, ground sample distance, band-to-band registration, and fraction of saturated pixels were calculated during ingest of a dataset into the SDP data management system. Additionally, calculations of image endlaps and sidelaps were made for comparison with contract specifications.

Because Space Imaging, LLC, was the first company to launch a spaceborne commercial high-resolution remote sensing system successfully, there was a great deal of interest in understanding the IKONOS satellite’s utility for science research and applications. Thus, NASA undertook a significant effort to characterize IKONOS performance independently. Several validation sites throughout the United States were used to characterize IKONOS data spatial response, geopositional accuracy, and radiometric accuracy. Scientists from the University of Arizona, South Dakota State University, and the University of Maryland contributed to NASA’s characterization effort. These scientists brought years of experience in NASA Earth Observing System (EOS) calibration and validation. NASA-led vicarious calibration efforts determined that Space Imaging's initial radiometric calibration coefficients were inconsistent with those produced by the NASA team (Pagnutti et al., n.d.). NASA collaborated with Space Imaging to investigate the inconsistency. As a result, the government-produced radiometric calibration results were incorporated into an updated set of Space Imaging calibration coefficients (Peterson, 2001). NASA also collaborated with the National Imagery and Mapping Agency (NIMA) and with the USGS—two government agencies utilizing IKONOS and other commercial data—to form the Joint Agency Commercial Imagery Evaluation (JACIE) team. The JACIE team collaboration resulted in a thorough characterization of the

IKONOS system and improvements in data quality (Zanoni et al., n.d.). Additional information regarding JACIE is included in section 5.3 of this report.

3.0 Earth Science Enterprise Research and Applications Relevance

3.1 Data Use

To gain insight into how SDP data supported ESE science and applications, scientists utilizing SDP data were asked to categorize their research into one of the ESE Science Research or Application Theme Categories in place at that time. The Science Research themes included Land Cover-Land Use, Terrestrial Ecosystems, Solid Earth, Land Surface Hydrology, Physical Oceanography, Polar Environment, and Other. Application Research categories included Resource Management, Community Growth, Disaster Management, Environmental Quality, and Other.

The majority of research projects involved the Land Cover and Land Use Change theme area. Within this research theme area, data uses included the development of a national land cover database, the study of island ecosystems, the detection of selective logging sites, and the monitoring of changes in rivers, coastal wetlands, glaciers, and urban environments. In the Environmental Quality research theme area, SDP data was used to test water quality, to study coral reef environments, and to identify mosquito habitat location. In the Resource Management category, the data was used for precision agriculture and for assessing forest inventories. The Terrestrial Ecosystems research theme area included projects that utilized SDP data to measure water, energy, and carbon fluxes, to validate vegetative indices, and to generate global land cover products. SDP data was also used in support of several archaeology projects and Verification and Validation activities (**Figure 4**).

While considering data use, it is necessary to explain the evolution from NASA's Mission to Planet Earth to the current Earth Science Enterprise. NASA renamed the Mission to Planet Earth to the Earth Science Enterprise in 1998. The name change was intended to convey the goals of the program more clearly and to focus more directly on research being conducted. In this way, the ESE pioneered the emerging discipline of Earth System science. At that time, the enterprise was reshaped to address key questions in major Earth system science disciplines: land surface cover, near-term and long-term climate change, natural hazards research, and atmospheric ozone (NASA, 1998). With the release of the NASA Earth Science Enterprise Research Strategy for 2000-2010, the enterprise defined a hierarchy of scientific questions designed to answer one overarching question: **"**How is the Earth changing and what are the consequences for life on Earth?**"** The hierarchy of questions focuses on variability, forcing, response, consequence, and prediction, and illustrates how the Earth operates as a system, with responses to both natural and human-induced change and a feedback process. To further address the scientific questions, the ESE program established five research themes: (1) biology and biogeochemistry of ecosystems and the global carbon cycle; (2) atmospheric chemistry, aerosols, and solar radiation; (3) global water and energy cycle; (4) oceans and ice in the Earth system; and (5) solid Earth science. This research strategy aligns with the U.S. Global Change Research Program, with some overlaps and some differences, to ensure that research addressed primary Earth System science issues and questions (NASA, 2000). Additionally, the current ESE includes an Application Division, which has identified 12 National Applications is the areas of Agricultural Efficiency, Air Quality, Aviation, Carbon Management, Coastal Management, Disaster Management, Ecological Forecasting, Energy Management, Homeland Security, Invasive Species, Public Health, and Water Management. Through ESE's Applications Division, NASA Earth science research results will be extended to achieve societal and economic benefits.

During the course of the SDP, data use was categorized by the ESE science and applications themes. However, as demonstrated in the following section, use of SDP data spanned a wide range of research and applications relevant to both past and present NASA Earth Science themes.

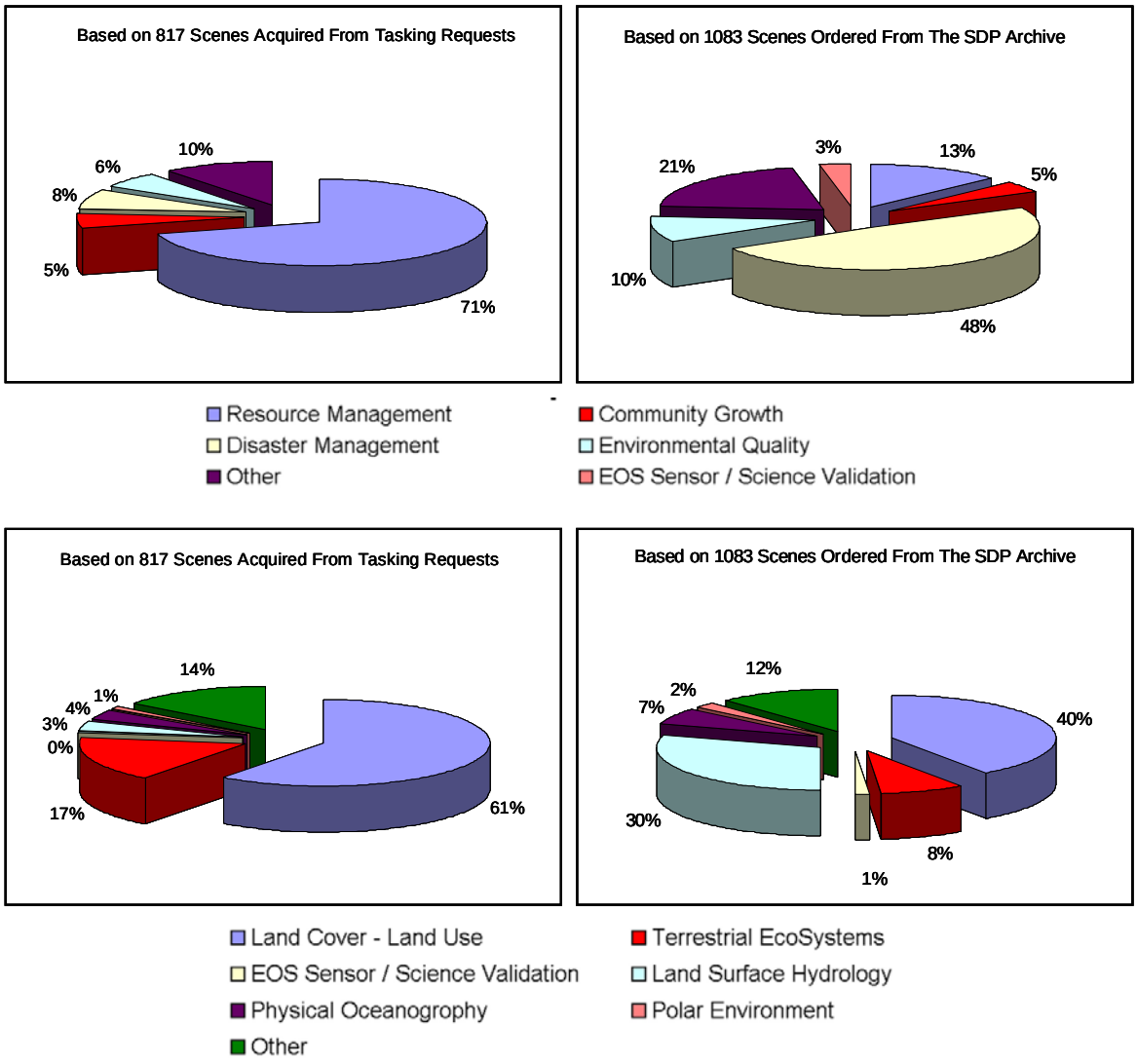


Figure 4. Data use percentages subdivided by the applications research category (top) and the science research category (bottom).

3.2 Earth Science Research and Applications Project Examples

Several SDP projects are described below, categorized by data vendor. They illustrate examples of both the SDP data use and the impact of the SDP data on research projects.

3.2.1 Earth Satellite Corporation

The EarthSat SDP products have provided, for the first time, complete global coverage of orthorectified Landsat TM and MSS data. EarthSat purchased data from foreign ground stations; this data has never

before been contained in the United States' archive. Through the SDP, EarthSat provided NASA affiliated researchers with orthorectified Landsat data, which has been used in a variety of ways.

3.2.1.1 Global Land Cover

The Global Land Cover Facility (GLCF) in College Park, Maryland, is a funded member of NASA's Earth Science Information Partnerships program, whose research emphasis has been to address critical global- and regional-scale terrestrial Earth systems science issues that are central to NASA's Earth Science Enterprise. One of the GLCF's foremost roles has been to enable the pursuit of Earth science research through the distribution of high quality raw and derived datasets, such as global land cover products. Through its extensive infrastructure and partnership with the University of Maryland Institute for Advanced Computing Studies, the GLCF has utilized the latest data distribution technologies. Through NASA's SDP, the GLCF's research projects have been enhanced by the availability of Space Imaging's IKONOS and EarthSat GeoCover products. In some cases, EarthSat data has allowed coregistration of Landsat 7 imagery to provide higher quality time series. In other cases, the data has provided the GLCF and its user community with an effective resource for validating coarse-resolution products.

Over the past several years, the GLCF, in partnership with NASA's SDP, has made it its goal to build a robust body of products and services for the Earth science community. The availability of multiple characterizations of the Earth's surface and, most recently, the EarthSat orthorectified TM coverage, has led to a better understanding of the Earth and the manner in which it is changing. Synoptic coverage of the Earth's forest cover, in combination with the EarthSat GeoCover coverage obtained from the SDP, has enabled natural resource managers at the local and national levels to better understand forest dynamics (**Figure 5**). When one considers that some of the more inaccessible areas of the Earth are of considerable interest to researchers because of their preservation or conservation value, high-resolution remote sensing emerges as a viable alternative to ground study.

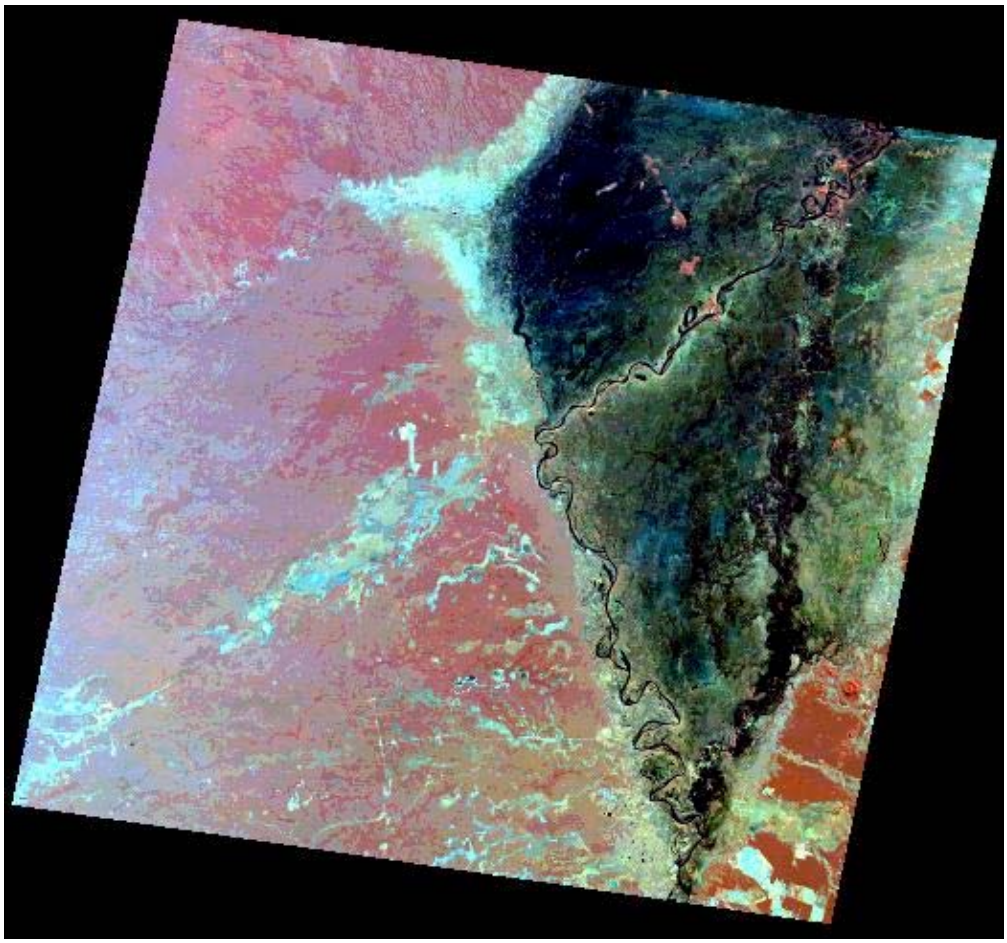


Figure 5. EarthSat GeoCover Landsat 4 image acquired on May 10, 1989, showing the intersection of Bolivia (north/northwest region), Paraguay (south/southwest region), and Brazil (darker region to east). This image has been used to analyze deforestation and land cover change and is an example of how humans and the environment interact.

3.2.1.2 Ground-level Ozone Effects

Imagery from EarthSat provided the necessary data for a project conducted by NASA-affiliated researchers at the University of Rhode Island titled "The Effecting Factors on Ground-level Ozone in the Northeastern United States." The study was designed to develop innovative models in regional land use and land cover change study. As part of the research, the impact of land use and land cover change on the environment was investigated, specifically, the factors influencing the concentration of ground-level ozone in the northeastern United States. Remote sensing observations have rarely been used to quantify the effects of natural and human factors on the spatial variability of ground ozone. However, the SDP data was used to extract land cover information of the Northeastern United States, including the states of Massachusetts, Rhode Island, Connecticut, New Jersey, and Delaware; the District of Columbia; and parts of New York, Pennsylvania, and Virginia. Urban land cover change between 1990 and 1999 was examined for this region. This project revealed a relationship between the urban land cover change and the ground ozone dynamics. The results revealed that a positive correlation exists between land surface temperature, which is affected by land-cover change, and ground ozone concentration, and that urban sprawl, in particular, is one of the factors that caused the ozone problem in the region. EarthSat GeoCover Landsat data (**Figure 6**), as a single data source, provided homogeneous regional coverage with the same

spectral bands; in this way a large regional phenomena could be studied under the same conditions. Such unified regional coverage has not been available from other sources.

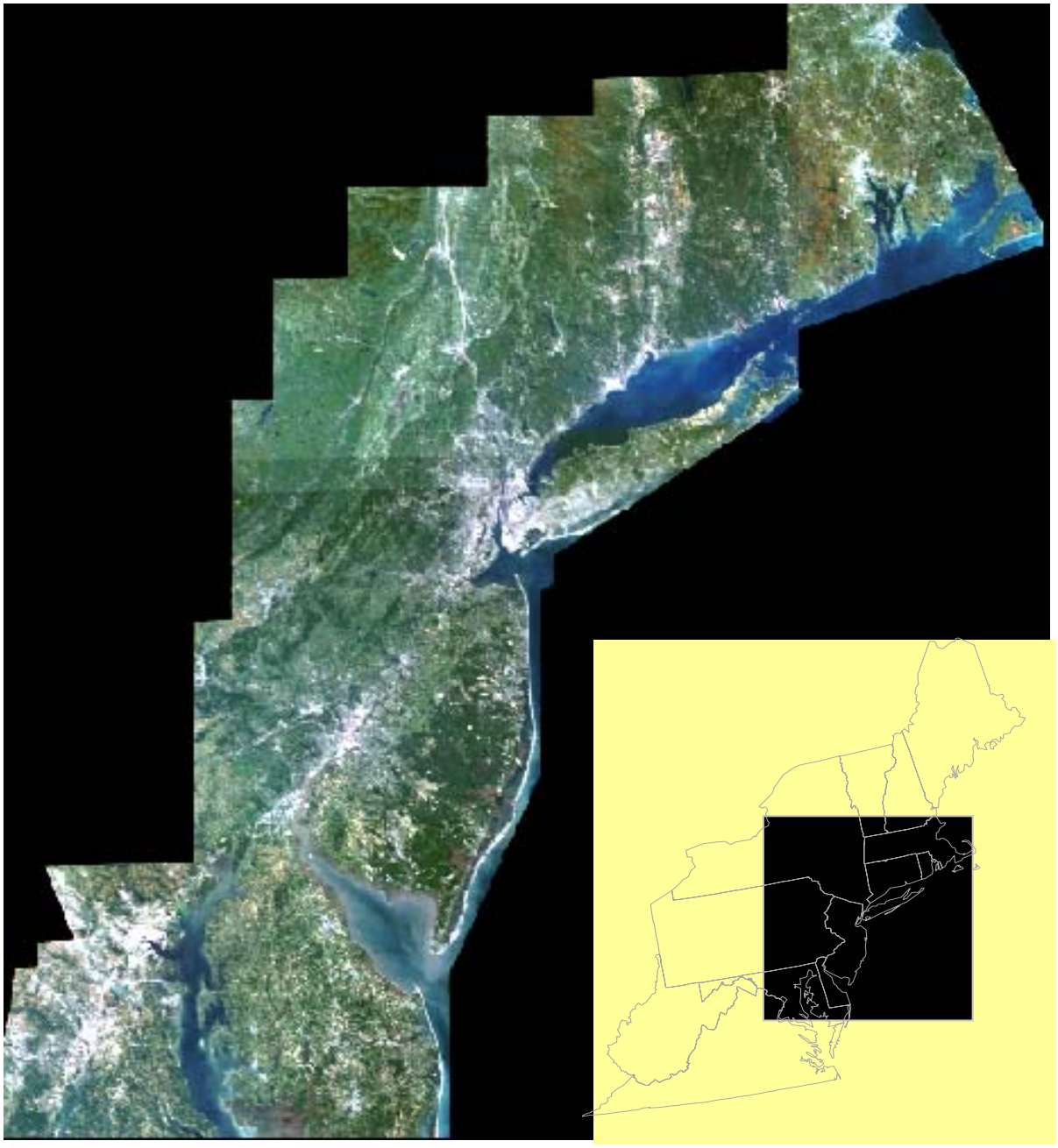


Figure 6. EarthSat GeoCover Landsat TM imagery displaying the study area location for a University of Rhode Island project titled "The Effecting Factors on Ground-Level Ozone in Northeastern United States."

3.2.1.3 Terrestrial Carbon Storage in Russia

Researchers at the Remote Sensing and Geographic Information Systems Laboratory at Woods Hole Research Center, Woods Hole, Massachusetts, have studied land-use change and changes in terrestrial

carbon storage in Russia. These changes have occurred as a result of recent environmental disturbances. The carbon balance of northern mid-latitude terrestrial ecosystems remains uncertain; recent estimates vary as to whether the region is a source (an extra source of carbon) or a sink (where carbon is absorbed). By integrating EarthSat Landsat data (**Figure 7**), forest inventory data, results from ecological studies, agricultural and forestry data on land use change, and MODIS satellite data and products, researchers are trying to determine the current distribution of carbon storage and changes in the storage over the last decade. Researchers stratified Russia into 25 regions using four geographic blocks (European, West Siberia, Central Siberia, and Eastern) and then subset the blocks further by forested vegetation zones. They sampled 15 of those regions using forest inventory data and Landsat data to create continuous biomass layers; these samples will form the basis for a Russia-wide carbon distribution map using MODIS data. The work thus far encompasses 4 sites: one region in Leningradsky, one region in Kursk, and two regions in Khabarovsk.

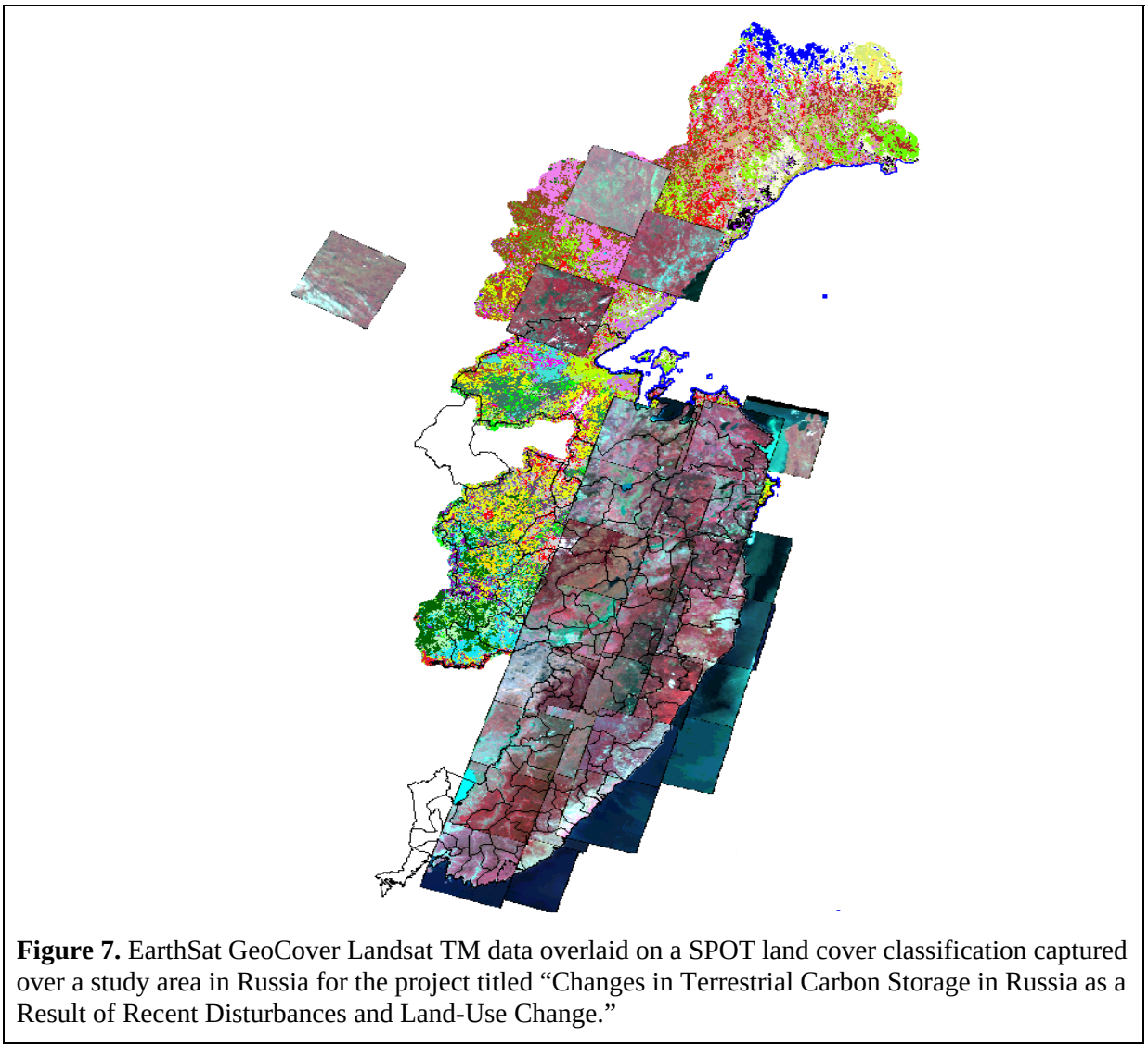


Figure 7. EarthSat GeoCover Landsat TM data overlaid on a SPOT land cover classification captured over a study area in Russia for the project titled “Changes in Terrestrial Carbon Storage in Russia as a Result of Recent Disturbances and Land-Use Change.”

3.2.1.4 Remote Sensing Imagery for Sustainable Development

The Center for GIS and Remote Sensing at the University of South Carolina (USC), which combines the campus-wide geographic information system (GIS) support program, the campus University Consortium on Geographic Information System initiative, and the existing NASA-sponsored Affiliate Research Center (ARC), was formed in 2000 to focus on GIS and remote sensing topics.

One of USC's GIS and remote sensing project sites is the Tanzania/Kenya coastal zone; this area is a part of the U.S. Government's Geographic Information for Sustainable Development initiatives. The challenge of coastal region studies lies in arriving at enduring solutions to the complex problems facing these unique areas, where considerable ecosystem services and high human population pressure coincide. The goal of the Tanzania/Kenya project is to combine remote sensing data with GIS technologies for use in coastal resource management, planning, and decision making. The research findings from this project were compiled into the National Academy of Sciences (NAS) report titled "Down to Earth: Geographic Information for Sustainable Development in Africa" (National Research Council, 2002a) and was published in hardcopy and presented at the World Summit on Sustainable Development in Johannesburg, South Africa, in September 2002 and elsewhere.

To develop sustainable development projects, it is essential to have fundamental framework data. This normally takes the form of "framework-foundation-data" consisting of (1) geodetic control, (2) orthoimagery, and (3) digital elevation and bathymetry data. The National Academy committee concluded, in the above-mentioned report, that the most important global dataset available for (2) orthoimagery was the GeoCover orthoimagery dataset prepared as part of NASA's SDP Program by Earth Satellite Corporation (**Figure 8**).

The NAS report described in detail the significance of the global dataset and how NASA and others share it at a minimal cost through a very effective user interface. It is the only true relatively high spatial resolution dataset (approximately 30 x 30 m) global orthoimage dataset that can be used by most developing countries as a very important starting point in sustainable development projects. The report also described other critical "thematic-framework-information" of significance for most sustainable development projects. One of the most important is land cover. It became clear that the global Landsat GeoCover land cover dataset prepared by EarthSat available in the NASA's SDP program is the only global land cover dataset at approximately 30 x 30 m. Thus, this derivative product is very important on a global basis for sustainable development projects; many times, it is the only relatively accurate land cover database available for entire countries. EarthSat is also completing a 2000 version of the land cover dataset.

Figure 8. EarthSat GeoCover Landsat TM data captured over the Tanzania coastal area in June 1991.

3.2.1.5 Forest Health and Land Use Change

The cover of the September 2000 issue of *Photogrammetric Engineering & Remote Sensing* presented an EarthSat Landsat TM mosaic compiled from 1275 scenes from the NASA SDP (**Figure 9**). This dataset has also been used for change detection research being performed by the U.S. Department of Agriculture (USDA) Forest Service. In 1994, a formal agreement between the Forest Service and East Africa led to the creation of the Forest Health Center in Nairobi. In September 1999, another formal agreement was developed between the Forest Service and the Faculty of Forestry and Nature Conservation, Sokoine University of Agriculture. In February 2000, the Forest Service began a two-year evaluation of forest health and land-use change in the Eastern Arc Mountains of Kenya and Tanzania. Main components of this study include satellite imagery, permanent plots, and a Web page. Under a NASA-USDA Memorandum of Agreement, the Forest Service used the EarthSat imagery from the SDP for this study. Analysis of the 1980s and 1999 TM imagery showed a forest area reduction of over 30 percent (USDA Forest Service, 2001).

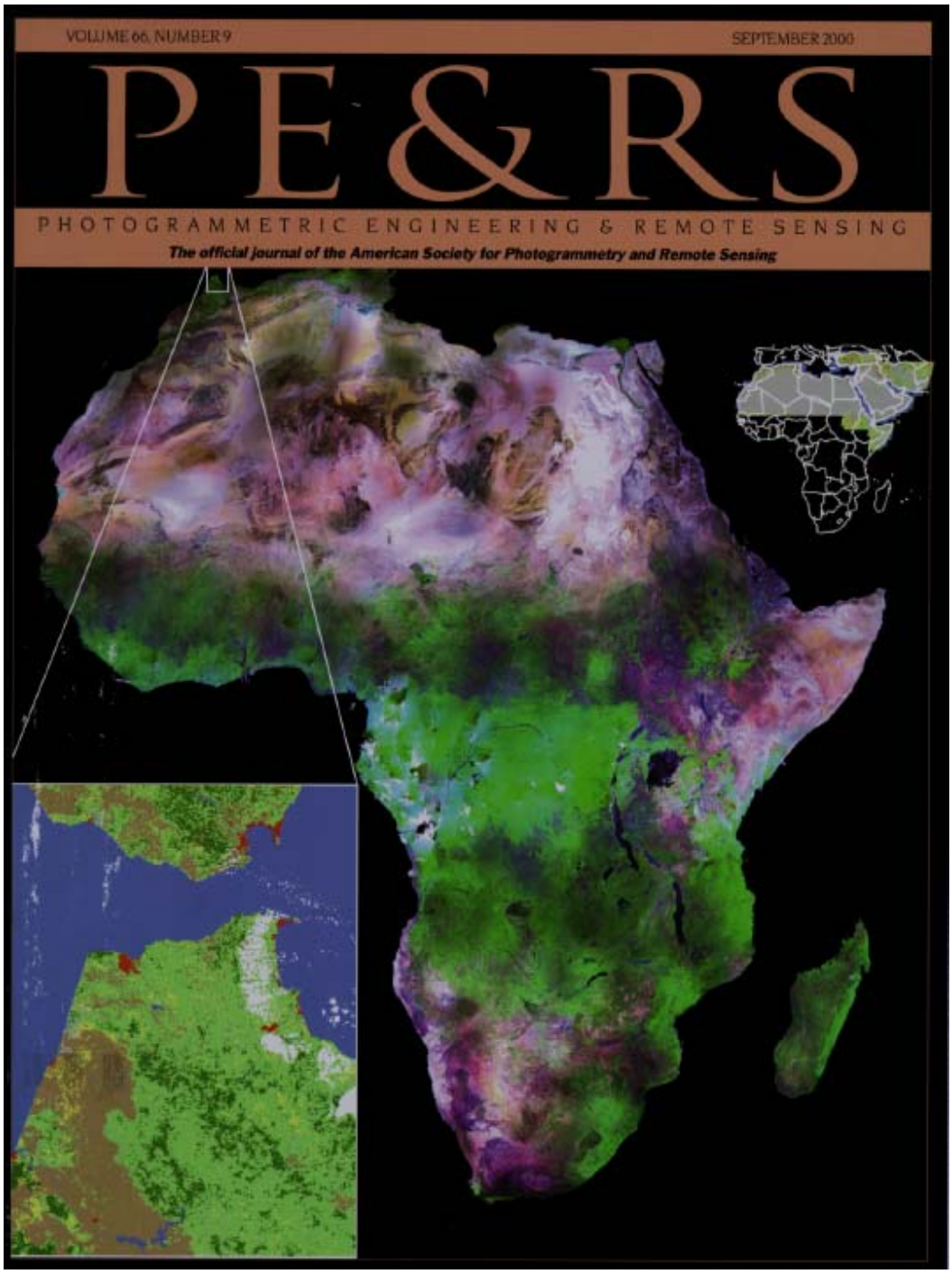


Figure 9. EarthSat GeoCover Landsat TM mosaic compiled from 1275 scenes accompanied a cover story in the September 2000 issue of *Photogrammetric Engineering & Remote Sensing*.

3.2.1.6 NASA-CCAD Mesoamerican Biological Corridor Project

In 1998, NASA signed a Memorandum of Understanding with the Central American Commission on Environment and Development (CCAD) in support of cooperative research focused upon monitoring the

Mesoamerican Biological Corridor (MBC). In this effort, NASA and the CCAD collaborated to utilize remote sensing technologies to map and monitor land cover of the MBC. This region has suffered from high rates of deforestation because of human migration and agricultural expansion. The goal of the collaboration between NASA and the CCAD has been twofold: (1) to conserve, protect, and help to balance ecologically the environment by developing regional forest cover maps and to monitor changes in forest, and (2) to use this information to help sustain economic development. Working in conjunction with the University of Maine in Orono, Maine, NASA's ESE has been helping to create a regional satellite database to monitor forest condition and environmental change throughout the MBC. By using remote sensing data provided through NASA's SDP, this region's first detailed land-use maps have been developed

The EarthSat GeoCover SDP orthorectified TM imagery was essential to the success of the NASA/CCAD project. SDP images were acquired for the 1990s and TM scenes were purchased for 2000 to analyze forest cover and deforestation within the MBC (**Figure 10**). The results of the forest cover and change detection were published and were used by the Central American government and by conservation organizations to develop conservation strategies concerning sustainable forest management within the MBC. Spatial information about the status of forest cover in the MBC was never available before and convinced the Central Americans that NASA remote sensing technology was an essential tool needed to monitor natural resources continuously throughout the region.

The EarthSat GeoCover TM data was also used to develop a quality remote sensing training program for Central American scientists on how to map land cover and deforestation using images for each of the seven countries. As a result of the successful training program and applied research leading to an assessment of forest cover and change in the region, the CCAD and the U.S. Agency for International Development are funding the University of Maine and Oregon State University to conduct an expanded land cover, change detection, and carbon-monitoring project for the region.

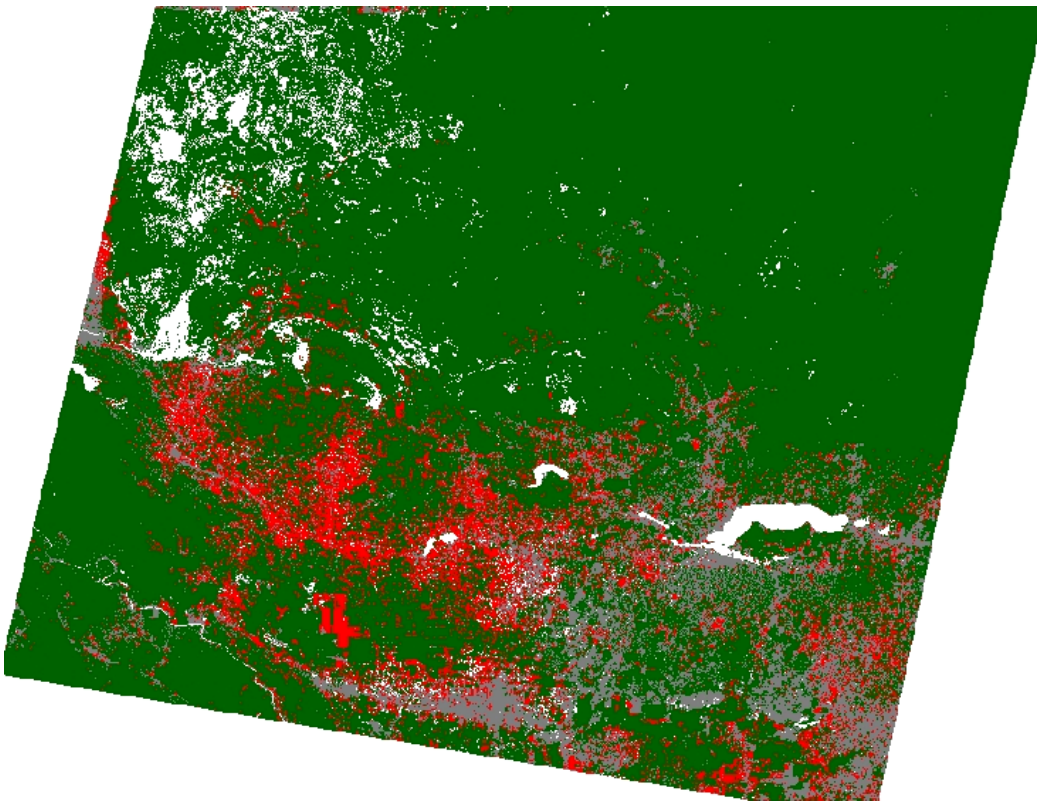


Figure 10. Land cover change classification over Central America created using EarthSat GeoCover Landsat imagery from 1986 and Landsat data from 1997. The green represents forest, the gray represents non-forest, and the red represents forest clearing between 1986 and 1997.

3.2.1.7 Calibration/Validation Research: Uniform Site Identification

As part of the SSC independent validation effort, scientists at NASA's SSC have used the EarthSat GeoCover African TM scenes to identify uniform sites for vicarious calibration and signal-to-noise ratio (SNR) studies. Particular sites in Libya exhibited very high uniformity, thus facilitating the tasking of Space Imaging's IKONOS satellite over these sites to explore radiometric calibration and SNR assessments. The sites exhibited such uniformity that slight differences in gain coefficients between focal plane arrays on IKONOS could be observed (**Figure 11**). Space Imaging has since corrected these differences. This study demonstrated that the global EarthSat GeoCover dataset could be used to identify uniform sites for potential use in radiometric characterization.

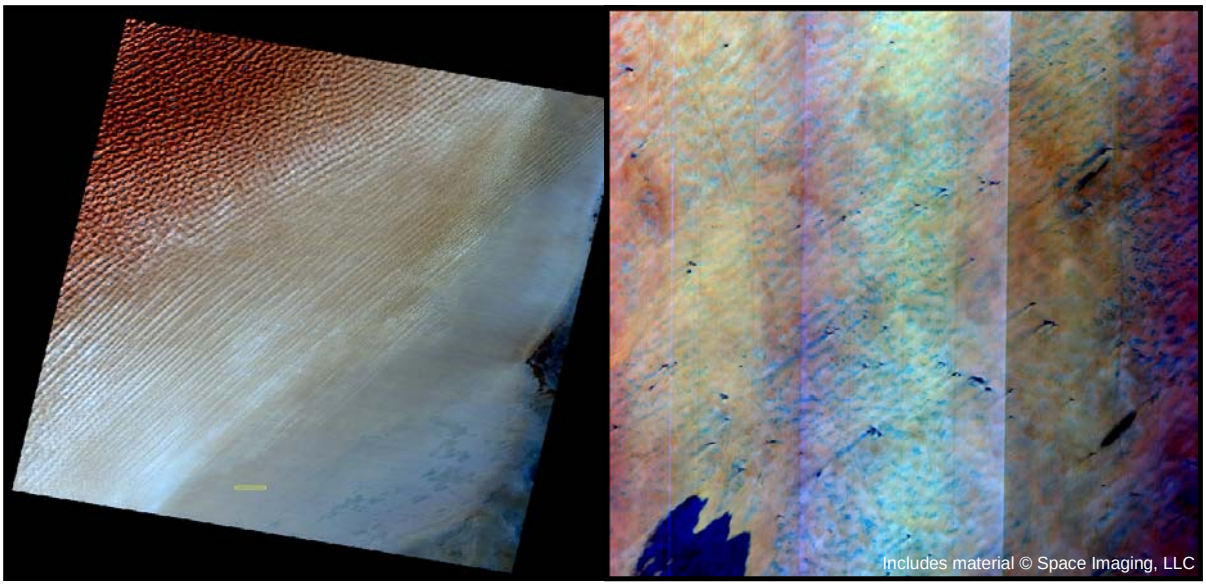


Figure 11. EarthSat GeoCover Landsat TM scenes over Africa used to identify uniform sites to assist in IKONOS validation efforts. Left: Most uniform ~11 km x 1 km area "Libya 1" identified by yellow rectangle (RGB: 3,2,1). Right: IKONOS image centered over the ~11 km x 1 km area found in the Landsat TM analysis (RGB: 3,2,1).

3.2.1.8 Identifying Possible Terrorist Locations

Counter-terrorism work utilizing EarthSat GeoCover imagery has improved the existing maps of the northwest Pakistan-Afghanistan border area. Using background scenes from video footage, regional cultural geography, and military history gained from extensive fieldwork in Paktia and Paktika (provinces of eastern Afghanistan), NASA-affiliated researchers at the University of Cincinnati have acquired imagery to determine possible terrorist locations in the volcanic rocks of eastern Afghanistan. The imagery was imported into a GIS, and the public NIMA geographic database was superimposed on the imagery to determine the regional extent of these volcanic-like rocks. A short list of likely targets was then forwarded to the United States government in October 2001. This combination of remotely sensed geology and geography may develop as a tool that will have a significant impact on the fight against terrorism.

3.2.1.9 Virtual Exploration of the U.S.

A NASA ESE partnership project with the USGS used EarthSat data to create a CD set of GeoCover imagery titled "United States of America Digital Landsat Mosaics." This CD set allows the viewer to explore the entire United States from a variety of scales ranging from states and regions to individual cities and towns. The perspective view from the Landsat series provides new insight on the land surface conditions of the United States to decision makers, teachers, and students who wish to enhance, protect, and explore our country. Approximately 3000 CD have been made, and some of these CDs have been sent to NASA Headquarters, to the SSC Education Office, and to the USGS EDC. Examples are shown in **Figure 12**.

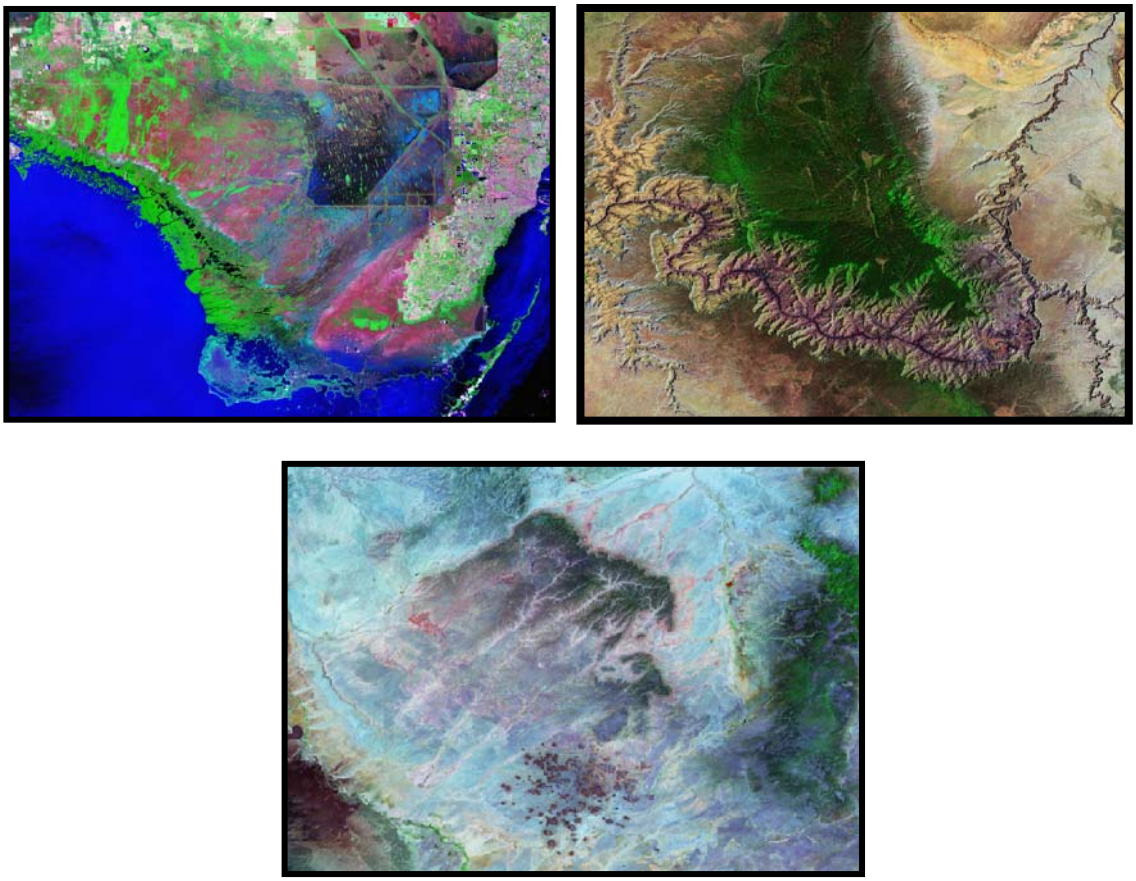


Figure 12. Mosaics of EarthSat GeoCover Landsat TM data captured over the Florida Everglades (top left), the Grand Canyon (top right), and the Painted Desert in northeastern Arizona's Petrified Forest National Park (bottom image). These mosaics were created for the "United States of America Digital Landsat Mosaics" CD set.

3.2.2 DigitalGlobe/Intermap

The DEMs available from the DigitalGlobe/Intermap STAR-3*i* sensor have proven to be invaluable in many fields of research. STAR-3*i* has provided imagery of Alaska that, in the past, has not been available (NASA's Shuttle Radar Topography Mission (SRTM) did not acquire imagery at high latitudes). Additionally, STAR-3*i* has provided imagery of volcanoes in Java, Indonesia, that simply could not be acquired from existing, non-classified spaceborne systems. STAR-3*i* has also been used over Central America to assess deforestation and has been instrumental in glaciological research directed toward studying the effects of global warming.

3.2.2.1 Solid Earth Applications: Alaska Aviation Safety

NASA's Langley Research Center's Aviation Safety Program (AvSP) has partnered with the Federal Aviation Administration (FAA), aircraft manufacturers, airlines, and the Department of Defense. This partnership supports the national goal announced by President Clinton in February 1997 to reduce the fatal aircraft accident rate by 80 percent in 10 years and by 90 percent over 25 years (NASA, 2003a).

The Synthetic Vision Project is an aviation safety project that is being conducted by NASA's AvSP. Most fatal aircraft accidents result primarily from limited visibility; the availability of synthetic vision could potentially reduce low-visibility conditions as a contributing factor in aircraft accidents. The state of Alaska has very few roads, and travel throughout the state relies heavily upon aviation. The Alaska flight corridors have a limited number of mountain range passes that are used for flight; these corridors must be used in even the most inclement weather conditions. Consequently, crash statistics reveal that these particular flight corridors have reported many aircraft crashes.

NASA's AvSP is helping to develop a synthetic vision system, or a virtual-reality display system, for aircraft cockpits. Synthetic vision systems (SVS) use aircraft attitude information derived from onboard sensors and position obtained from the Global Positioning System to portray a clear, daylight representation of the out-the-window scene on a graphics display device in the cockpit, greatly improving the pilot's situational awareness. Crucial to making this concept work are the underlying terrain, obstacles, and airport databases that are queried by the system to synthesize the outside environment for display to the pilot.

STAR-3*i* high-resolution digital elevation imagery of these corridors have been made available to the AvSP through NASA's SDP, and a 3-D visualization concept has been developed to help train pilots to fly through difficult flight corridors that are unique to Alaska's landscape. The SDP data that was collected in Alaska is being used by the SVS project to generate the required databases for simulation testing of the Juneau, Alaska, region in support of the FAA Capstone program, and for simulation testing of various Alaskan mountain passes to support local research into terrain portrayal and symbology for head-down displays. Special databases were generated that are used by the SVS displays mounted in front of the pilot in the cockpit, and others were developed to provide out-the-window views for various flight simulators. Depending upon the intended use, the 3-D databases are either colored based on elevation or are draped with photographs or high resolution IKONOS satellite imagery (**Figure 13**) also acquired through the SDP.

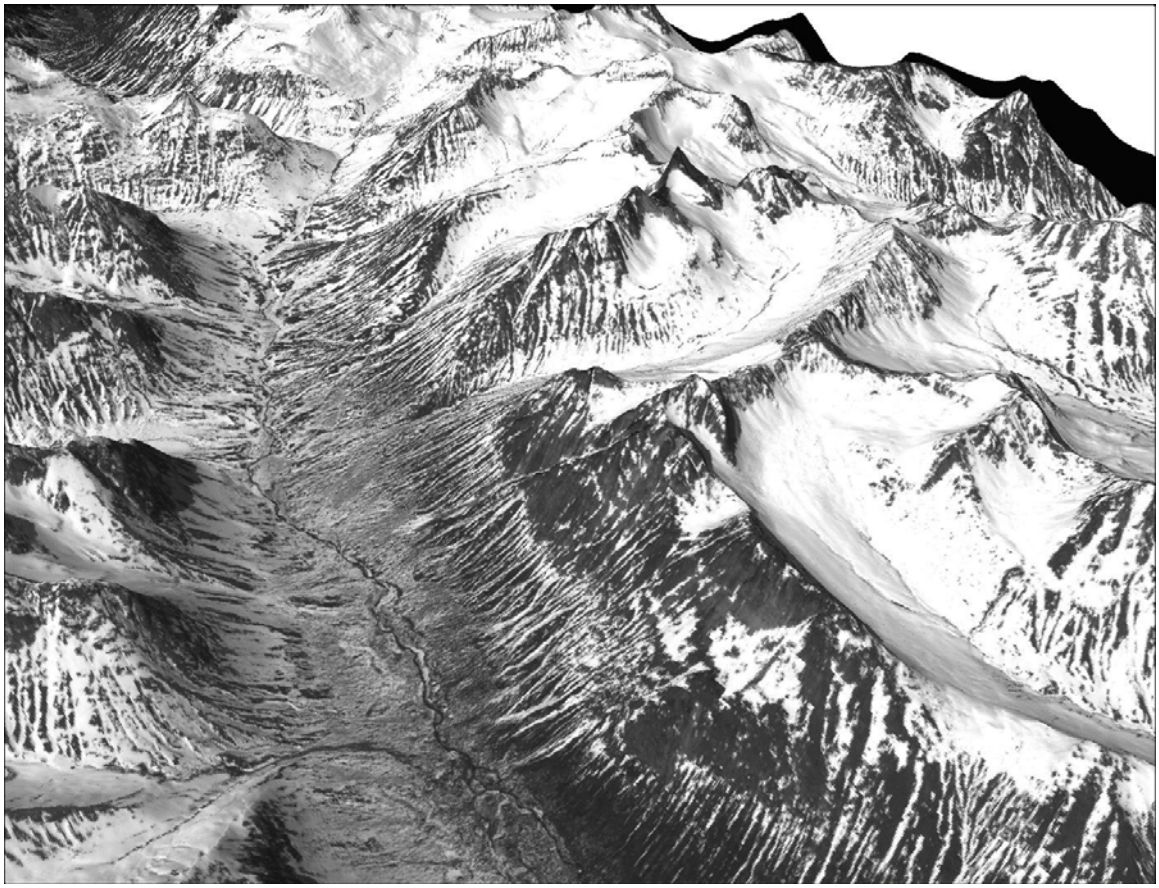


Figure 13. DigitalGlobe/Intermap STAR-3*i* IFSAR terrain model draped with IKONOS imagery acquired in Alaska used for flight scenarios for the Symbology Development-Heads Down Display simulation experiment.

3.2.2.2 Solid Earth Applications: Volcanic Topography

The Hawaii Institute of Geophysics & Planetology used the DigitalGlobe/Intermap STAR-3*i* imagery over Java, Indonesia, to validate NASA EOS Interdisciplinary Science Team Investigations. The team's effort includes working on the development of algorithms to study volcanoes. The data requested through the SDP program enabled the study of the topography of different volcanoes in Java at a horizontal and vertical resolution that could not be obtained by spaceborne methods. The imagery focused on mapping hazards at some of the world's most active volcanoes to understand how these volcanoes change after large eruptions. The imagery was also assessed for mapping potential active volcanic regions. An example image set of a volcanic region is shown in **Figure 14**.

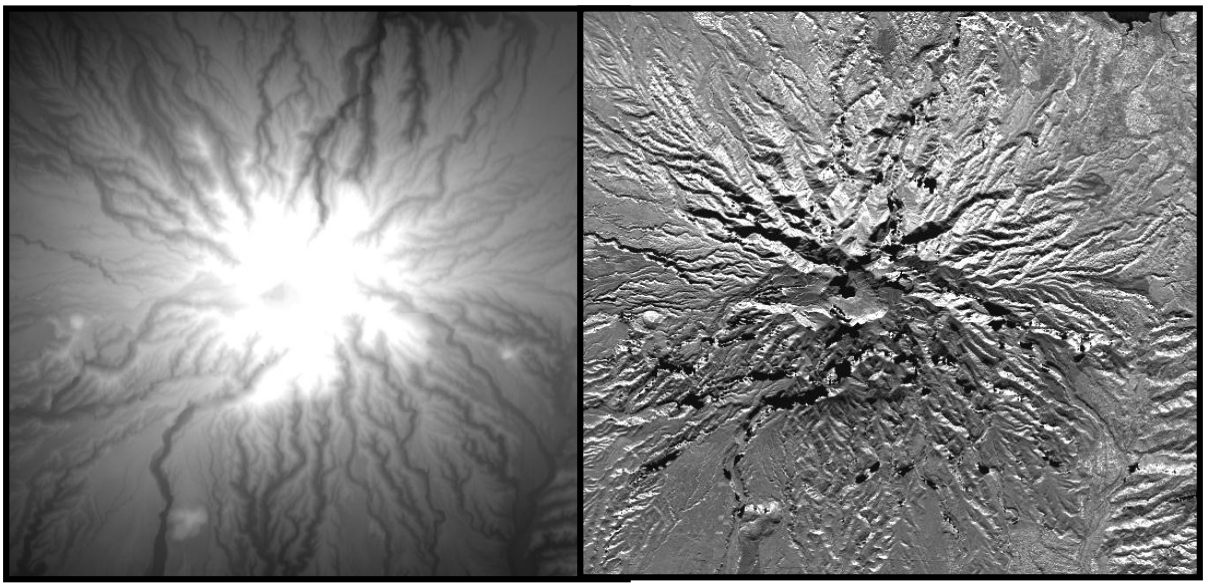


Figure 14. DigitalGlobe/Intermap STAR-3*i* digital elevation model and orthorectified radar image map over Java, Indonesia.

3.2.2.3 Arctic Region Hydrology

The Alaska Synthetic Aperture Radar Facility (ASF) is located in the Geophysical Institute at the University of Alaska in Fairbanks, Alaska, and is primarily funded through NASA's Earth Observing System. The ASF's primary mission is to acquire, process, and archive satellite imagery to advance polar research and Earth science. Assessments of the role of terrestrial hydrologic processes in climate change and, in particular, the processes unique to Arctic hydrology are lacking. Studies for hydrological and permafrost research have been severely limited because of the low resolution of DEMs available for these study areas. However, with the availability of DigitalGlobe/Intermap STAR-3*i* high quality DEMs through NASA's SDP, previously impossible computer modeling is now possible. Studies that involve assessing regional impacts of climate change using a combination of image analysis and field validation within Alaska have now been enabled.

Driven by scientific interest in high latitude climate change and its impact on global climate change, a series of intense hydrologic studies have been ongoing in the Kuparuk River watershed on the North Slope of Alaska (funded presently by National Science Foundation (1993-present) and initially by the Department of Energy (1985–1992)). The acquisition of the STAR-3*i* DEM of this basin has allowed the study of many detailed hydrologic processes that previously were not possible. Furthermore, because of the higher resolution of the STAR-3*i* DEM data over the USGS DEM data, the most advanced spatially distributed hydrologic models to generate both drainage networks and areas for the four catchments being studied were able to be used (Imnavait Creek, Upper Kuparuk River, Kuparuk River, and Putuligayuk River; **Figure 15**). Because these are relatively young surfaces underlain by permafrost, the drainage networks are poorly developed both in the foothills and in the coastal plain, making a high resolution DEM a requirement for even the most basic hydrologic analysis. Topography is very important to many hydrologic processes, such as soil moisture distribution and snow distribution; having precise DEM data enables the routing of soil moisture in the active layer above the permafrost and redistributes the heterogeneous snowpack by modeling the windy environment using accurate slopes and aspects provided by the DEM. In summary, the STAR-3*i* data has enabled the conduct of essential hydrologic research, analysis, and modeling at a previously impossible level of detail on a large scale Arctic watershed.

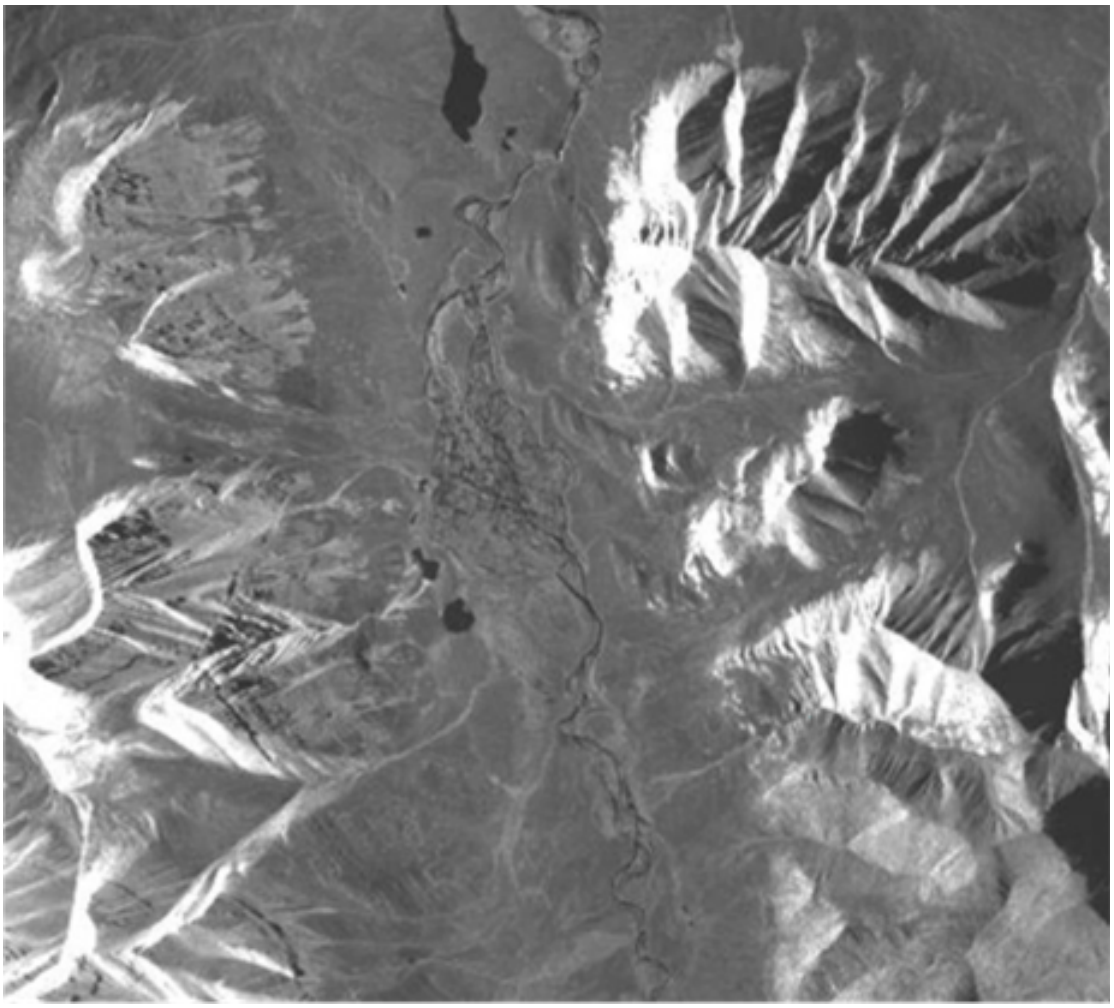


Figure 15. DigitalGlobe/Intermap STAR-3*i* orthorectified radar image map captured over a study area in Alaska for a project titled “Kuparuk River Basin: Watershed-Scale Analyses of an Arctic Drainage–A New High Resolution Digital Elevation Model.”

3.2.2.4 NASA-CCAD Central American Archaeology

The Central American Commission on Environment and Development has used STAR-3*i* imagery over nine sites in seven countries for mapping natural, historic, and other cultural resources. Traditional archaeological survey techniques have become inefficient and costly. Remote sensing helps achieve archaeological research objectives, which involve detecting, mapping, locating, and analyzing associated landscapes. The STAR-3*i* data has been used to map several previously unknown archaeological sites, to assess deforestation, and to map hurricane damage. One thousand years ago, the forests of the Peten were nearly destroyed by the ancient Maya, who after centuries of successful adaptation finally overused their resources. After centuries of regeneration, the Peten now represents the largest remaining tropical forest in Central America. However, current inhabitants are abandoning the successful adaptive techniques of the indigenous population in favor of the destructive techniques of monoculture and cattle raising, resulting in rapid deforestation. Remote sensing and GIS analysis are being used to address issues in

Mayan archeology as well as to monitor the effects of increasing deforestation in the area. The data has also provided an improved base map for registering other geospatial data. Through the use of remote sensing and GIS analysis, researchers are attempting to answer questions about the past to protect the resources of the future (**Figure 16**).

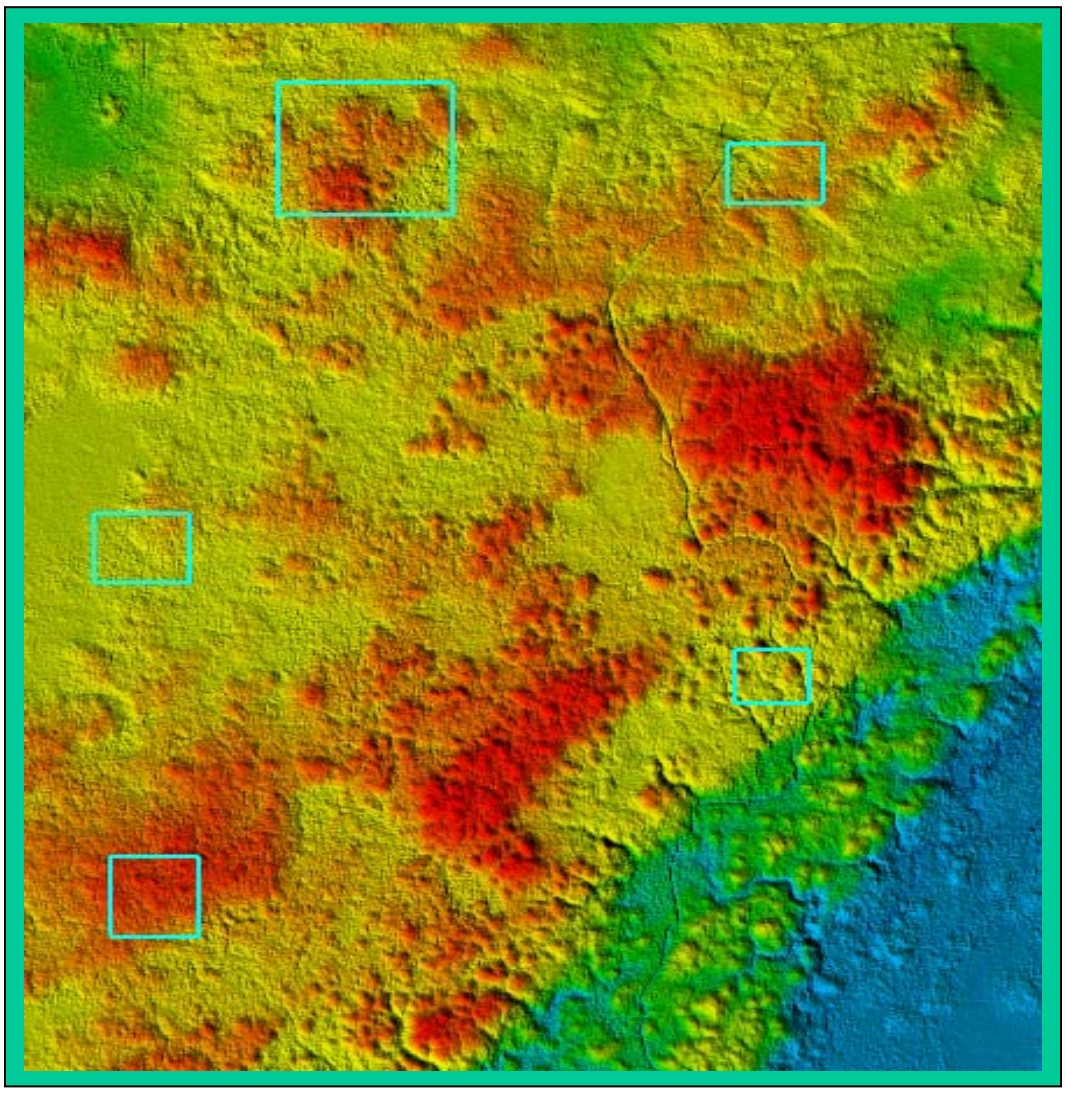


Figure 16. DigitalGlobe/Intermap STAR-3*i* digital elevation model of Rio Bravo Reserve in Belize. Mayan ruins are shown in cyan squares.

3.2.2.5 Glacial Dynamics

NASA's SDP program has been beneficial to the glaciological research program at the Geophysical Institute of the University of Alaska–Fairbanks. Multi-year changes in surface elevations on glaciers and ice sheets express the integrated effect of changes in flow and mass balance. Elevation changes are thus a direct measure of glacier dynamics and of the amount of water the ice mass has contributed to rising sea levels during the measurement interval. The accuracy of the DigitalGlobe/Intermap STAR-3*i* DEM of Bagley Ice Valley would have been difficult to obtain in any other way, and it has enabled researchers to estimate the spatial distribution of elevation changes on this large ice field since the early 1970s, when

aerial photography was used to derive the USGS topographic maps and DEMs of this region. The results have provided a unique map-plane view of the distribution of elevation changes on Bagley Ice Valley (**Figure 17**) that are an important complement to the program of small-aircraft laser altimeter measurements on glaciers that is also being carried out at the Geophysical Institute. NASA's SDP program has also played an important role in the research of piedmont glaciers on the Gulf of Alaska coast that appear to be rapidly thinning because of climatic warming. Acquisition of additional Intermap GT-3 DEMs of Malaspina Glacier and in the St. Elias Range has enabled this research.

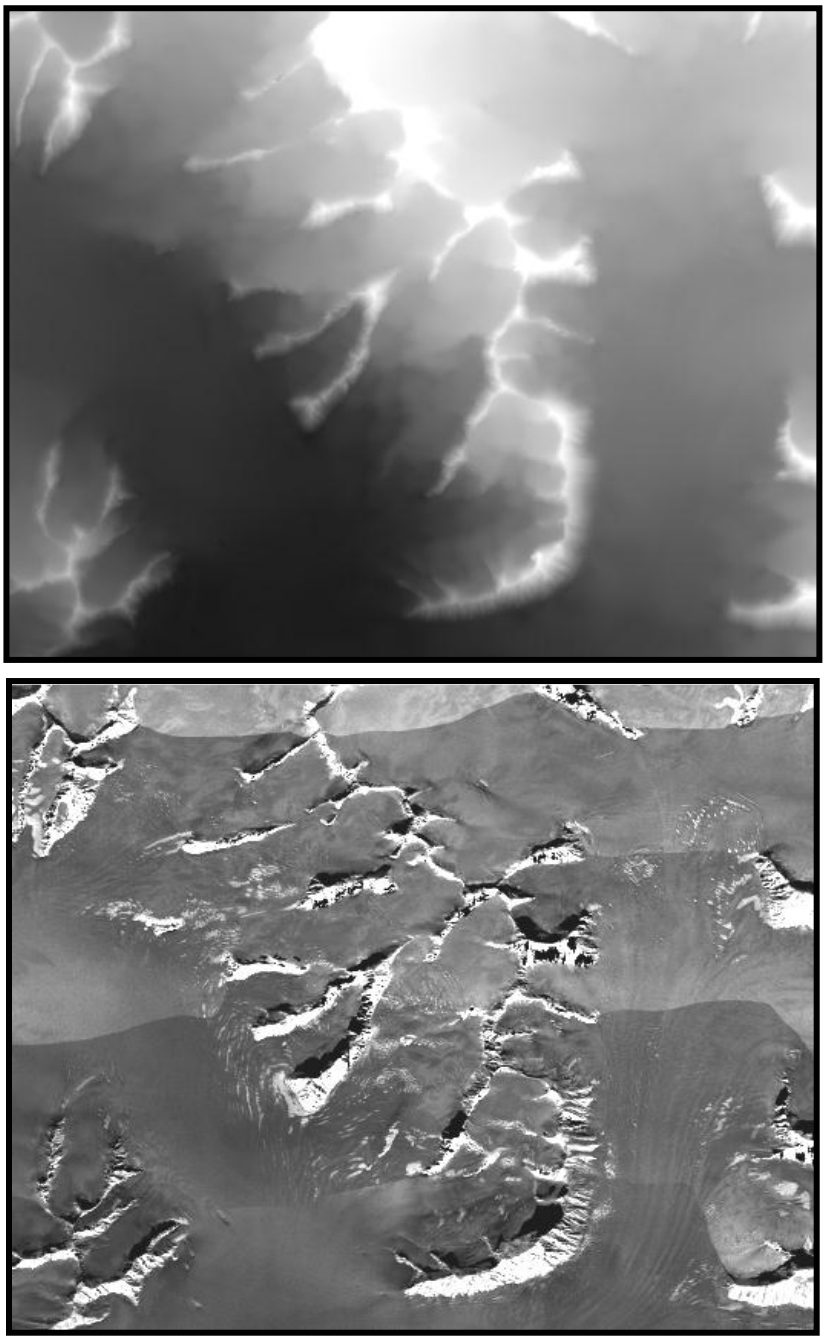


Figure 17. DigitalGlobe/Intermap STAR-3*i* digital elevation model and orthorectified image over Bagley Ice Valley.

3.2.3 Positive Systems

Positive Systems ADAR 5500 data served as a model for future high spatial resolution, space-based, multispectral systems (e.g., IKONOS). Examples of how Positive Systems data have been used include the study of watershed modeling in Yellowstone National Park, precision agriculture applications in North Dakota, the study of land cover and land use in the Washington D.C. area, and visualization of archaeological dig sites.

3.2.3.1 Watershed Analysis

The NASA-Montana State University (MSU) TechLink Center in Bozeman, Montana, is a NASA-funded technology transfer and commercialization center. The center receives its principal funding from NASA's ESE. The NASA-MSU TechLink's mission is to enable the availability of NASA-developed technology and resources, including the acquisition of remotely sensed data through NASA's SDP, for a variety of applications for natural-resource-based and technology-based industries. Remotely sensed data adds an innovative way to measure environmental factors and is helping to streamline a variety of resource management operations. Remotely sensed data has been used for ecosystem analysis and for monitoring stream and riparian areas to help understand long-term changes.

One of the most daunting challenges facing land cover/land use change research is developing scientifically valid indicators for monitoring ecosystem integrity at a regional scale. One method is to study streams and riparian areas to develop an effective methodology that indicates the ecological integrity of associated watersheds. Streams and riparian areas are the accumulation zones of environmental disturbances that occur through their watershed. Eroded sediments from a variety of environmental factors profoundly affect them. These disturbances introduce significant changes in stream sediment loads, morphology, and riparian vegetation. However, remote sensing researchers have ignored streams and riparian areas because the relatively low spatial and spectral resolution systems that have been available in the past were not conducive to successful analysis of these types of ecological areas. However, finer-scale imaging, such as the ADAR 5500 imagery provided by Positive Systems made available through NASA's SDP prior to the launch of IKONOS, made a breakthrough in the utility of remote sensing technology for both scientific and commercial applications for stream and riparian study**.**

The Yellowstone National Park provided a unique environment for the MSU study because the factors that affect stream morphology and riparian habitat are representative of those impacting watersheds and degrading streams throughout the western United States and in many mountainous environments worldwide. The ADAR 5500 datasets (**Figure 18**) were valuable to this project (1) as a coordinate base for coregistering other remote sensing data (because the data are georeferenced, have many visual tie points, and have high resolution (0.8 meter), (2) in field validation of classification of Landsat data of Yellowstone Park and the surrounding region, and (3) in enabling the long-term evaluation of changes in floodplains and riparian vegetation in the Yellowstone Park region. The data allowed researchers to explore a wide range of applications involving land use, land cover, terrain modeling, and improved estimates of plant biomass. The ADAR 5500 was successful in providing a map for current work and future change detection as well as the basis for a spatial model to predict future impacts.

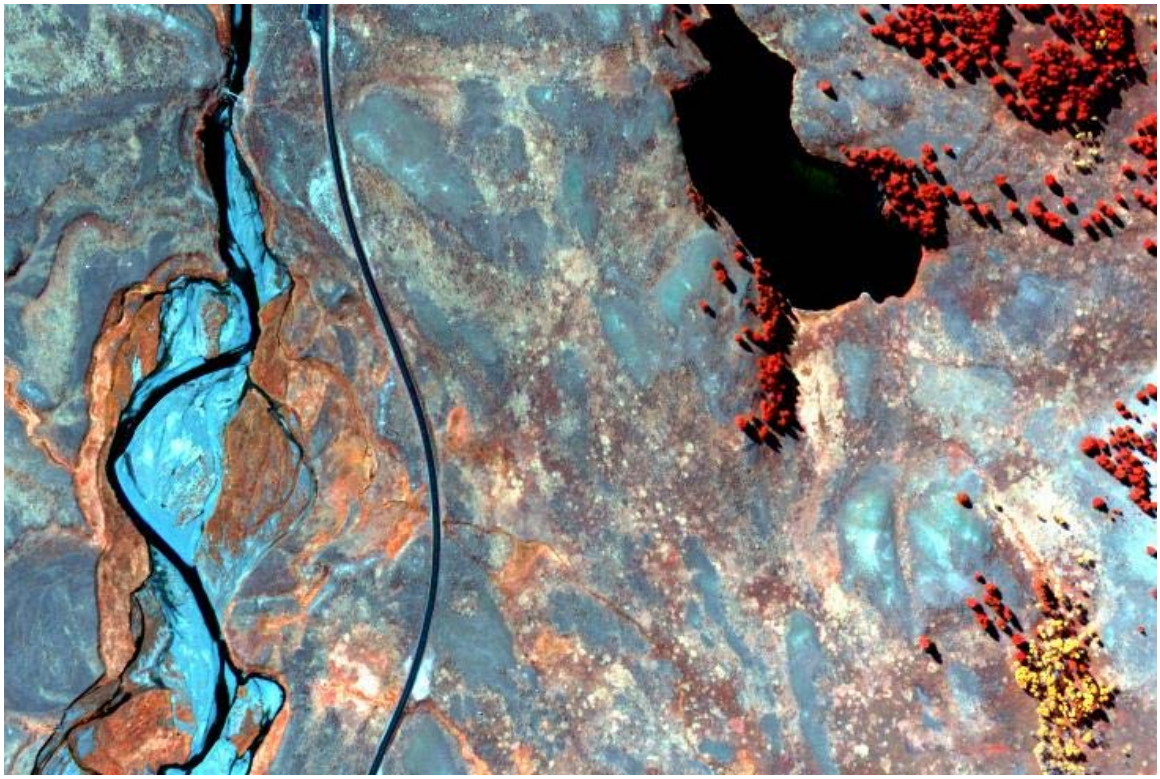


Figure 18. Positive Systems ADAR 5500 imagery used for watershed analysis in Yellowstone National Park.

3.2.3.2 Agriculture

The Upper Midwest Aerospace Consortium used Positive Systems ADAR 5500 imagery to show the benefits of high-spatial-resolution remote sensing multispectral data to the sugar beet farmers in St. Thomas Township, North Dakota (GEO World, 2000). The data collected provided the end users a first-time opportunity to receive high-resolution imagery and to extract information on prevailing field conditions from this imagery. Information obtained by the farmers included the identification of stress areas caused by wind damage, crops damaged by inundation, fertilizer skips, cultivator blights, planter skips, fungicide trials, and lodging. **Figure 19** shows the detail obtainable from ADAR 5500 imagery. The infrared channel is particularly useful in detecting crop stress *before* it becomes visible to the human eye, so data collected can provide detailed information regarding early signs of crop stress, which can help farmers take corrective measures. Smaller anomalies that could not be noticed on the ground could easily be identified on the imagery, helping to improve planting and management practices. Using SDP data, the consortium demonstrated that remote sensing data could reduce farmers' costs for soil surveys and fertilizer applications.

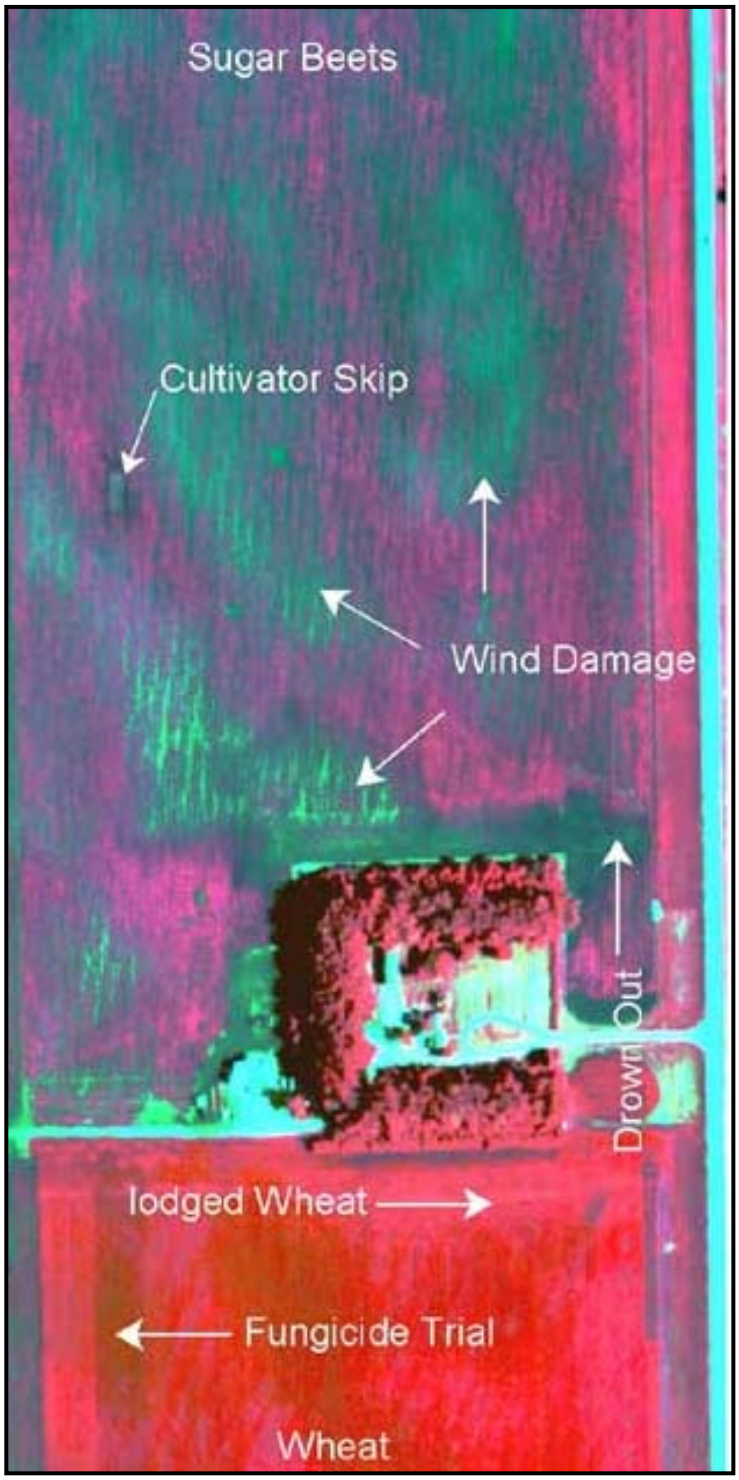


Figure 19. Positive Systems ADAR 5500 color composite showing fine details required by sugar beet farmers for improved farm management.

3.2.3.3 Environmental and Urban Landscape Monitoring

The Mid-Atlantic Regional Earth Science Application Center (RESAC) used ADAR 5500 multispectral data to examine and monitor the environmental status of land use/land cover in the Washington, D.C./Baltimore, Maryland, corridor. One of the goals of the Mid-Atlantic RESAC team is to develop maps and models to monitor the effects of urban growth and to predict its future direction. This information is used to assist urban planners and to help devise strategies to mitigate the undesirable effects of urban sprawl. Data received by the Mid-Atlantic RESAC through the SDP has been used to help resolve scaling issues associated with coarser scale imagery (e.g., Landsat TM) previously used for monitoring urban landscapes. The higher resolution ADAR 5500 imagery has aided urban planners by providing a clearer understanding of city growth and has enabled a more efficient and timely study of the effects of urban sprawl on the surrounding landscape. An example of the imagery used is shown in **Figure 20**.

Figure 20. Positive Systems ADAR 5500 imagery used for characterizing and monitoring environmental status of the Washington, D.C./Baltimore, Maryland, corridor.

3.2.3.4 Native American Archaeology

NASA SSC research scientists have used ADAR 5500 images provided by the SDP in archeological applications. ADAR images were used for airborne visualization of a known and extensively studied prehistoric Native American archaeological site (**Figure 21**). These images were compared to field survey

data as part of research into the use of multisensor imaging in archaeology. The high spatial resolution, multispectral images collected over bare ground revealed a series of linear features very near the location of the principal mounds both at the Parchman and Hollywood sites, which are located in agricultural fields in Mississippi. After analyzing the imagery, NASA and the University of Mississippi conducted field tests at these sites utilizing a variety of geophysical surveying techniques. The field survey data supported the initial findings derived from the airborne digital imagery. At least four buried prehistoric houses at Hollywood and two at Parchman were clearly delineated by the ground truth teams and matched the location and orientation partly visible in the ADAR imagery.

Figure 21. Positive Systems ADAR 5500 image captured over an archeological study area in Hollywood, Mississippi, in December 1999.

3.2.4 Space Imaging

Because the IKONOS spacecraft provided high-spatial-resolution data from an orbiting platform, Space Imaging data products have been extremely popular. IKONOS data has been used to bridge the gap between previously obtained remotely sensed imagery and fine-scale spatial heterogeneity on the ground. IKONOS imagery has also been used for the Large Scale Biosphere-Atmosphere (LBA) Experiment in Amazonia to produce mapping-quality imagery of previously inaccessible island landscapes, to introduce the public to this high-spatial-resolution data via the “Great Zooms” project, to perform sensor calibration and validation research, to observe changes in coral reef environments, to aide in the study of vector-borne disease, and to perform land product validation.

3.2.4.1 Forest Inventory Changes in Amazonia

Space Imaging data was used at the Complex Systems Research Center at the University of New Hampshire, where investigators coordinated the acquisition and distribution of IKONOS imagery for use in the NASA-supported LBA Experiment in Amazonia. The LBA was designed to create new knowledge needed to understand the climatological, ecological, biogeochemical, and hydrological functioning of Amazonia, the impact of land use change on these functions, and the interactions between Amazonia and the Earth system. IKONOS data has been used to examine end-member selection and validation for large-scale remote sensing of land cover; to detect selective logging in forests (**Figure 22**); to detect secondary forests' stage, age, and pathway; to detect fine-scale land use change; to detect forest canopy gap and natural disturbance; to determine forest basal area and biomass; and to describe landscapes for aircraft campaign information. In this activity, many LBA investigators from various LBA teams requested specific IKONOS imagery. A much larger set of registered users (approved using formal data sharing guidelines) requested and downloaded data using the NASA ESIP EOS-Webster (University of New Hampshire, 2003). In addition to the core LBA holdings, EOS-Webster also distributes some non-LBA NASA IKONOS imagery using the technology developed for serving LBA. This data is a very popular featured item on the EOS-Webster and is actively used by many investigators. IKONOS data shows features not visible from NASA government systems; additional detail affects and improves accuracy of carbon sequestration prediction.

Figure 22. Space Imaging IKONOS imagery used for a project titled "Large-scale Biosphere Atmosphere Experiment in Amazonia." Heterogeneity in the Amazonian forest from selective logging is depicted in this image.

3.2.4.2 Analyses of Sensitive Island Landscapes

NASA's Earth systems scientists have been conducting research utilizing IKONOS imagery to observe sensitive island landscapes. Remotely sensed data has been uniquely effective in developing new research directions in studies about the Earth and other planets. By examining highly sensitive, previously inaccessible oceanic island landscape systems as models for global/planetary observations, valuable information correlating to a variety of landscape responses to change can be considered. Unpopulated, relatively pristine islands are ideal control experiments for quantifying the sensitivity of landscape systems to differing forcings and climate change. These responses can include and may not be limited to coastline changes associated with rapid erosion, volcanic precipitate effects, landscape response to severe coastline storm surges, marine terracing due to island subsidence or sea level effects, and previously undocumented effects of ice accumulation. Through the SDP, over one dozen IKONOS datasets have been acquired from late 2000 to the present (**Figure 23**). This unique observational data offers promise for isolating key "sensitivity" variables in Earth science disciplines and offers a mechanism for development of response models that could be extended to more complex, continental regions. Without the SDP imagery, the ability to observe and measure changing features would not have been possible. The value of the SDP IKONOS imagery in these studies lies not only in direct scientific observations of these remote and sometimes inaccessible locations but also in providing cost-effective approaches for directing field observations and for suggesting additional remote-sensing-based experiments.

This application has also been directed to field analogue studies in support of future Mars exploration. NASA's SDP IKONOS imagery has been used to study landscapes on extremely remote locations on Earth to develop prospective studies on Mars. This study has influenced NASA's selection of a sub-meter imaging system for the Mars Reconnaissance Orbiter, scheduled for launch in 2005.

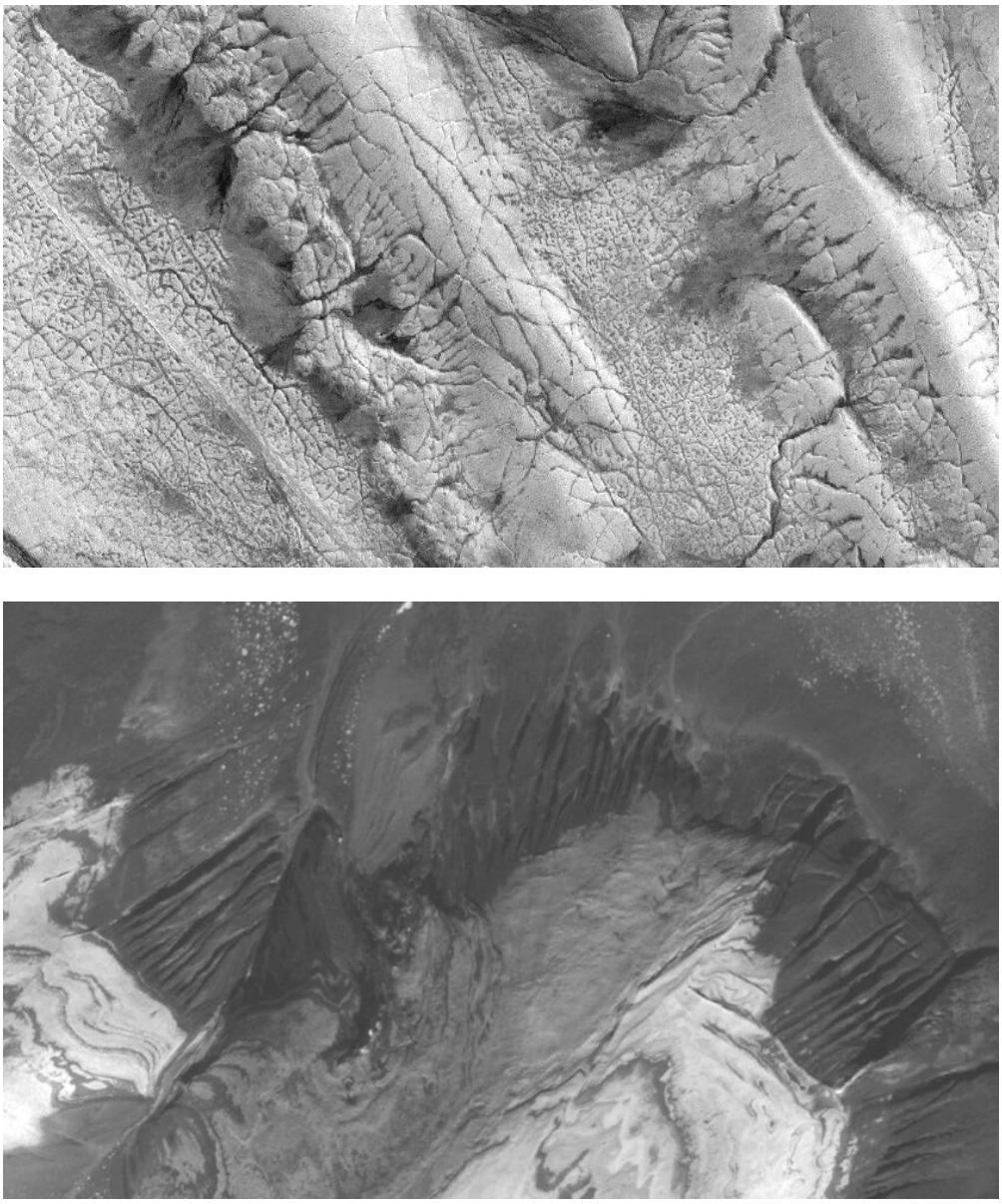


Figure 23. Space Imaging IKONOS imagery of Salar Grande evaporates and sediments (top); IKONOS imagery of Surtsey, Iceland, layers and gullies (bottom).

3.2.4.3 Visualizing Imagery at Varying Scales

SDP data acquired for the Landsat Project Science Office were used as part of the "Great Zoom" concept. The "Great Zooms" short sequences used MODIS, Landsat 7, and IKONOS data to create the illusion of "zooming in" to a particular location on Earth. The viewer is given a sense that a camera held high above the Earth is rushing toward the surface, is passing through layers of atmosphere, and then suddenly is stopping and floating in a virtual space just above the ground. The Science Visualization Studio at Goddard Space Flight Center rendered the zoom sequences. An example of several IKONOS scenes from the *Great Zoom into New York, NY: The World Trade Center* visualization is seen in **Figure 24** (NASA, 2001). Many of the zooms have been shown around the country and have enjoyed much popularity and

positive press. The vast majority of these scenes were released for Earth Day 2001 to highlight the ability of satellite imagery to document anthropogenic change. The Great Zooms introduced the public to an array of remotely sensed data, to the concept of various spatial resolutions, and to the idea of data fusion. The IKONOS data acquired through the SDP were essential to these zooms because they offered the highest resolution data contained in the zoom sequences.

Figure 24. Several Space Imaging IKONOS scenes from the *Great Zoom into New York, NY: The World Trade Center* visualization (NASA, 2001).

3.2.4.4 Sensor Verification/Validation

In-flight radiometric calibration of satellite sensors relies on both ground-based and airborne measurements of well-understood test sites at the time of sensor overpass, combined with an understanding of atmospheric models to predict the radiance at the sensor. These predicted radiances are compared with those reported by the sensor to evaluate the sensor's performance. When these approaches

are applied to multiple sensors viewing the same target (not necessarily at the same time), these instruments can be cross-compared with better precision.

The IKONOS imagery acquired through NASA's SDP was used to examine the accuracy of vicarious, radiometric calibrations for NASA's coarser resolution systems. This superior spatial resolution enabled a better understanding of both field validation approaches and expected accuracy limits.

Using IKONOS imagery, investigators at the University of Arizona's Remote Sensing Group developed techniques that allow the cross-comparison of terrestrial imagers to examine biases between these sensors (ASTER, MODIS, Enhanced Thematic Mapper Plus (ETM+), Sea-Viewing Wide Field-of-View Sensor (SeaWiFS), Advanced Land Imager (ALI), and Hyperion), and to discern differences as small as 2 percent between the sensors. This cross-comparison was possible because the high-resolution IKONOS imagery has shown that the primary source of uncertainty in the cross-comparison of imaging sensors is surface bi-directional reflectance effects. Utilization of this information showed that the uncertainties due to spatial heterogeneity of a test site and band-to-band differences could be readily minimized; this allowed accurate registration and scaling of poorer resolution sensors regardless of the site uniformity. Therefore, the imagery enabled the separation of the spatial registration effects from the other effects, which would not have been possible without the high-quality, high-resolution imagery that is provided by IKONOS. The order of magnitude difference between IKONOS and ETM+ enabled both a direct calibration of sensors and a cross-comparison. This understanding is important for application in future climate studies that will rely on the melding of datasets of varying spatial and spectral resolutions.

3.2.4.5 Coastal Reef Change Detection

NASA's ESE funded the Institute for Marine Remote Sensing (IMaRS) of the College of Marine Science located at the University of South Florida in St. Petersburg, Florida, to create an inventory of the world's coral reefs. This effort included studying and mapping reefs to help understand their recent and rapid deterioration. The ultimate objective of this effort is to use remote sensing to help provide a better understanding of changes occurring in coral reef communities and the subsequent effects upon the world's oceans.

With IKONOS SDP imagery, IMaRS was able to characterize and map coral reef ecosystems at scales that were not possible with previous field mapping techniques because of the excessive costs and the near impossibility of physically locating in the field and of subsequently accessing the world's abundant and sometimes remote coral reefs (**Figure 25**).

The IKONOS data provided through NASA's SDP was utilized for several studies. One use was direct comparison to historic aerial photography to study changes occurring on the reef environment over time. A key aspect was the comparison of results throughout coral reef biogeographic regions to obtain a global view of the potential of IKONOS for coral reef habitat mapping. All datasets quantified in a consistent fashion the decline in coral cover, thus validating the use of remote sensing techniques in coral reef change detection studies (Palandro et al., 2003a, 2003b).

IKONOS performances were also compared with other sensors, such as Landsat ETM+, Satellite Probatoire d'Observation de la Terre (SPOT), ASTER, and the MODIS/ASTER airborne simulator (MASTER) (Mumby and Edwards, 2002; Andréfouët et al., n.d.; Capolsini et al., 2003).

Several IKONOS images were also used to map and estimate the biomass of invasive brown algae on Polynesian reefs, providing key information to plan the harvesting of these algae for biotechnological applications (cosmetics) (Andréfouët et al., n.d.). The processing chain of IKONOS images acquired on aquatic environments was improved by implementing and testing an algorithm to remove sea surface noise frequent on IKONOS data (Hochberg et al., 2003). Additionally, IKONOS data are currently used for coral reef international research projects in the Bahamas, the Florida Keys, Australia, and French Polynesia. Involved institutions include the University of Puerto Rico, Western Washington University, the University of South Florida, the University of Queensland (Australia), and the University of French Polynesia (France).

The SDP provided support for enhancing the design of tools used for coral reef science and management worldwide and contributed to the education programs of several international institutions. The amount of research and work would not have been possible without this interface between commercial providers and the scientific community.

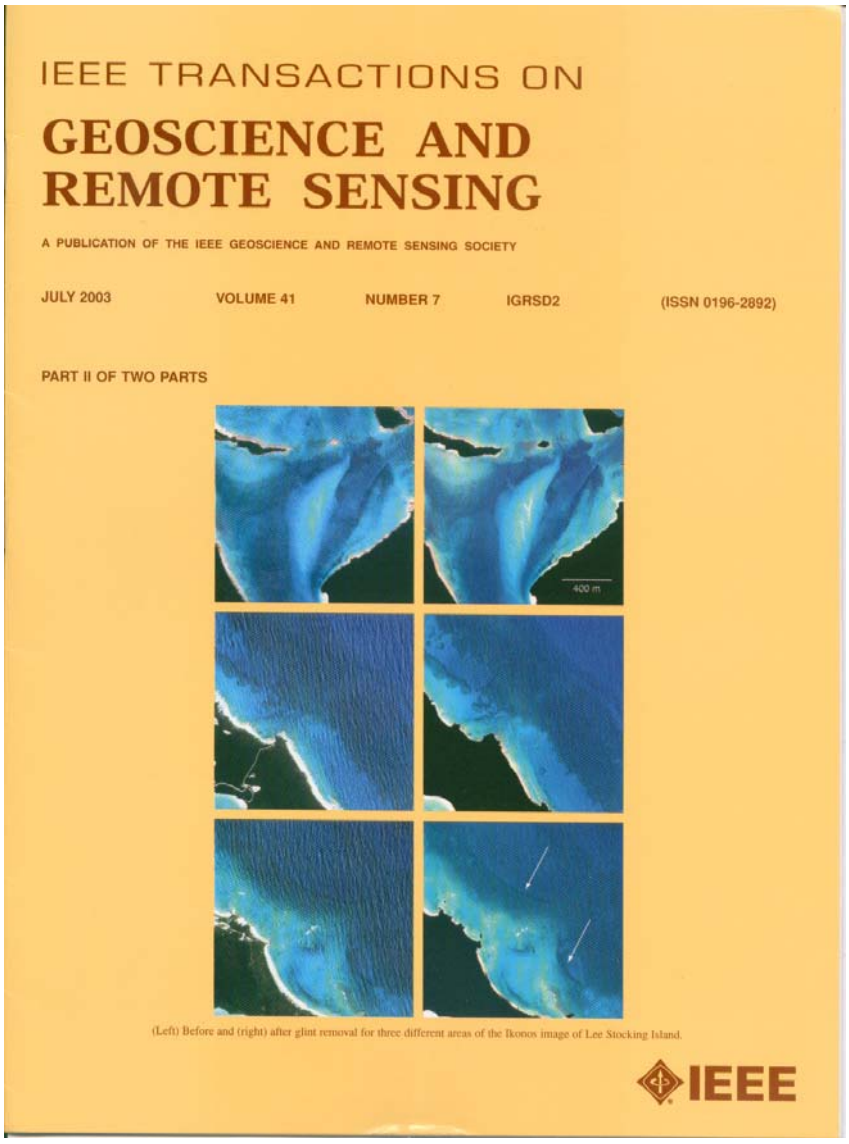


Figure 25. Shown above is Space Imaging imagery included as the cover story in the July 2003 issue of *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 41, No. 7. The article is titled "Sea Surface Correction of High Spatial Resolution IKONOS Images to Improve Bottom Mapping in Near-Shore Environments" by E.J. Hochberg, S. Andréfouët, and M.R. Tyler.

3.2.4.6 EOS Land Validation

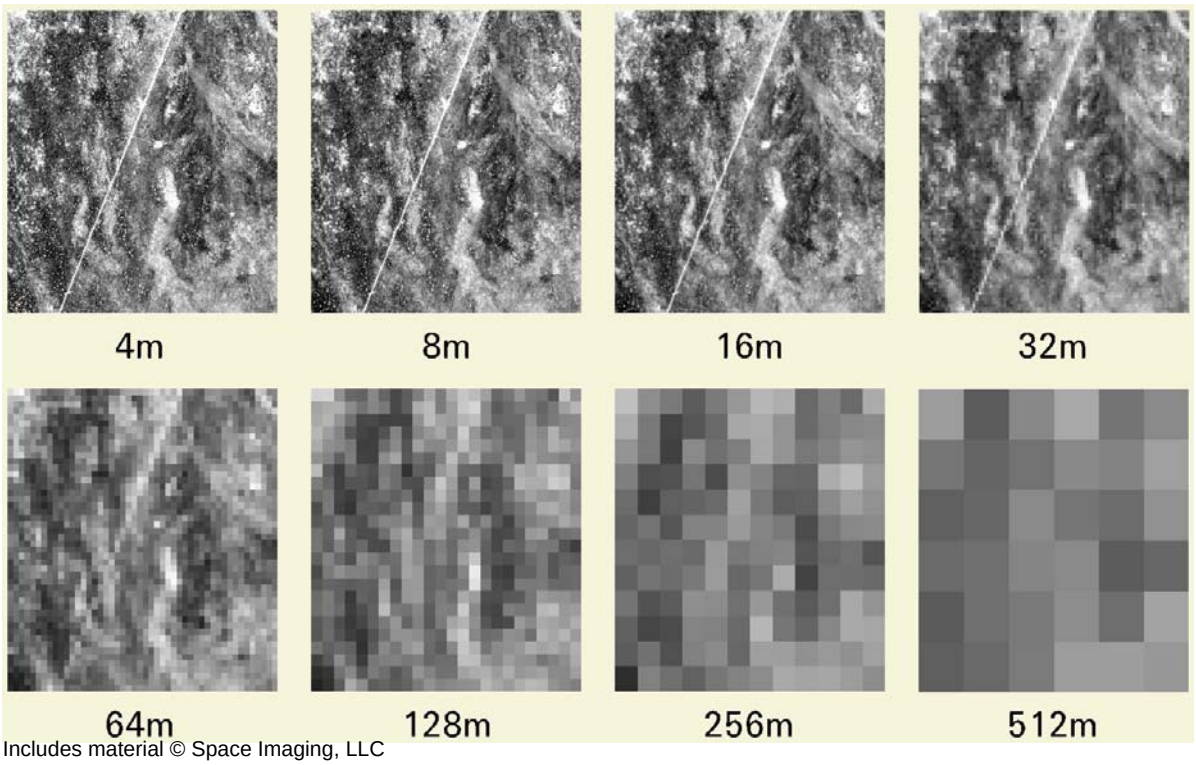
The MODIS sensors on NASA's EOS Terra and Aqua satellites play a vital role in the development of products that are used for measuring and monitoring land surface variables. These variables include land cover, leaf area index, fraction absorbed photosynthetic active radiation, and net primary production products. Validation of these products is crucial for assessing their accuracy for the scientific user community and for providing feedback to improve data processing algorithms. The MODIS land discipline team (MODLAND) is responsible for statistical and geostatistical analysis on multiple satellite sensor products.

As part of the MODLAND validation plan, key study sites were identified and evolved into the MODLAND Validation Core Site network. One of the main objectives for the core sites is to have consistent datasets available for each of the globally distributed sites. Another objective is to provide very high resolution imagery over the sites to support georeferencing, field reconnaissance, more coarse resolution image interpretation, and exploration of scales of spatial variation in biophysical properties of the landscape—all of which are important considerations for validation studies.

Not until recently has the Earth science community been able to meet the requirements of globally consistent imagery and very high resolution data. The SDP IKONOS imagery provided unique and beneficial imagery over the EOS Land Validation Core Sites. Without this high-resolution imagery, the only other option for such data would have been airborne imagery. Airborne image acquisition for several remote Core Sites is either cost prohibitive, too time consuming, unsafe, or logistically difficult or impossible. In light of these considerations, NASA's investment in high-resolution imagery through the SDP supplied the EOS Land Validation Core Sites with unique, globally consistent, critical validation datasets at a reasonable cost.

The MODLAND Core Validation Sites are also associated with BigFoot project study sites. Each BigFoot site is approximately 5 x 5 km in size and includes a CO_2 flux tower and an associated science program that involves carbon cycling, water vapor, or energy exchange. The BigFoot project evaluates ground measurements, IKONOS data acquired through NASA's SDP, and ecosystem process models at different study sites. Using this combination of *in situ* ecological data and remotely sensed data, the BigFoot project explores validation protocols and scaling issues to improve understanding of several MODLAND products.

IKONOS images were useful for planning routes to collect field measurements because some BigFoot sites are in remote locations. Land cover field measurements and observations are often directly related to Landsat imagery; however, complex spatial patterns existing on the landscape often limit interpretations. SDP imagery was most comprehensively used as an aid in developing a field sampling strategy. The extent to which imagery could be used as a surrogate for field measurements as well as determining the scale of variation in biophysical properties on a landscape were considered when using the imagery. IKONOS imagery was used to determine whether there were variation scales finer than that of 25 m and to track general spatial patterns of a biophysical variable. IKONOS imagery degraded from 4 m to 512 m, and corresponding semivariograms calculated from that imagery at Sevilleta National Wildlife Refuge could be compared (**Figure 26**). Landsat data could be used to determine the scale of variation in biophysical properties of this landscape; however, this was only confirmed by using finer resolution IKONOS data.



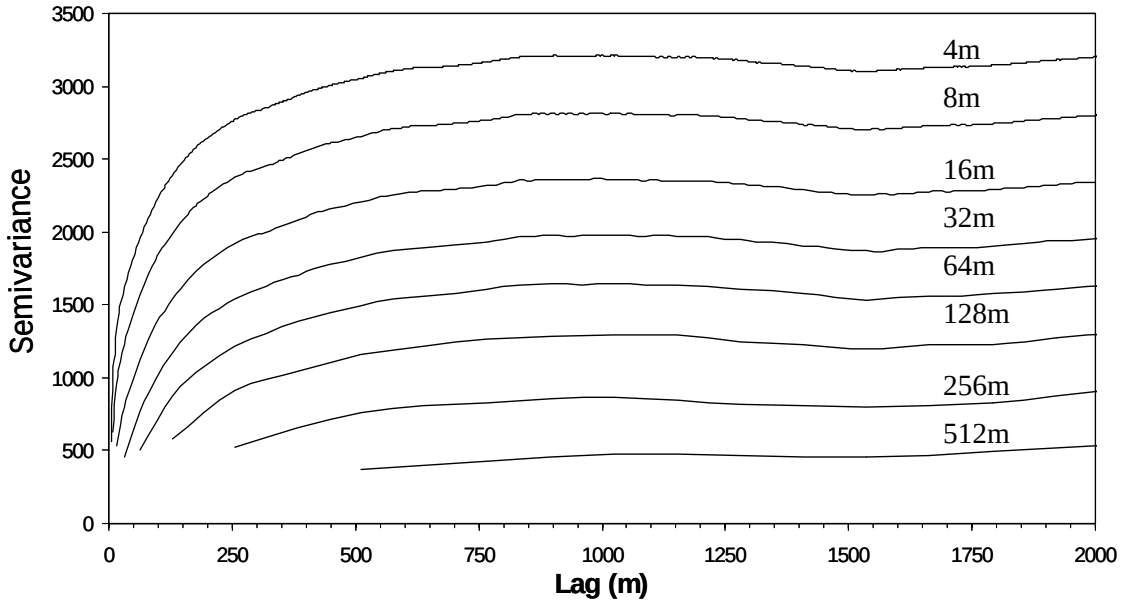


Figure 26. First principal component of 4-band Space Imaging IKONOS image over a 3 km by 3 km area of the Sevilleta National Wildlife Refuge in New Mexico (a BigFoot study site) spatially aggregated from 4 m to 512 m (top). Semivariograms were calculated from the imagery at each spatial resolution or grain size (bottom).

3.2.4.7 Malaria Prevention

NASA's Earth Science and Public Health program has been collaborating with the Uniformed Services University of the Health Sciences in Bethesda, Maryland, to examine the utilization of GIS techniques and remote sensing data at various scales to study environmental determinants of vector-borne disease in several countries. For example, the number of cases of malaria in South Korea has tripled since the 1960s. The close proximity of buildings, military posts, and other housing projects to rice paddies and potential mosquito breeding sites suggest that this problem will continue to grow unless these issues are addressed.

Mosquitoes and their habitats need to be studied to understand high-risk areas for disease. High-resolution imagery could be considered an excellent tool for local-scale mapping of mosquito habitats, which include marshes, streams, ponds, and other land cover. The detailed IKONOS imagery provided information about these locations that would have been difficult to obtain in the field (**Figure 27**). Once preliminary field surveys of possible mosquito breeding sites have been mapped on a local scale, they could be used in conjunction with remotely sensed imagery to create a regional model of potential risk for malaria transmission, and the necessary preventative measures could then be taken.

3.3 Publications

Probably the most striking evidence regarding the impact of SDP data is the number of publications and presentations that have incorporated SDP data and related results. SDP data users report having 80 articles published in, submitted to, or in preparation or review for a peer-reviewed journal. Additionally, these researchers have made 199 conference presentations and have produced 25 Web products/articles, 9 reports, and 7 educational presentations. A comprehensive bibliography citing 320 references is included in **Appendix D.** Each reference also notes the primary investigator for the project, the NASA project title, the NASA grant number, and the specific type of remote sensing data that was utilized for the project. Of the studies represented in this reference, 34 utilized EarthSat data, 13 utilized DigitalGlobe data, 24 utilized Positive Systems data, and 273 utilized Space Imaging data. Examination of these references could provide additional information on a variety of specific studies and data uses. Because the nature of science research is generally long-term, many SDP projects are ongoing and may result in future publications.

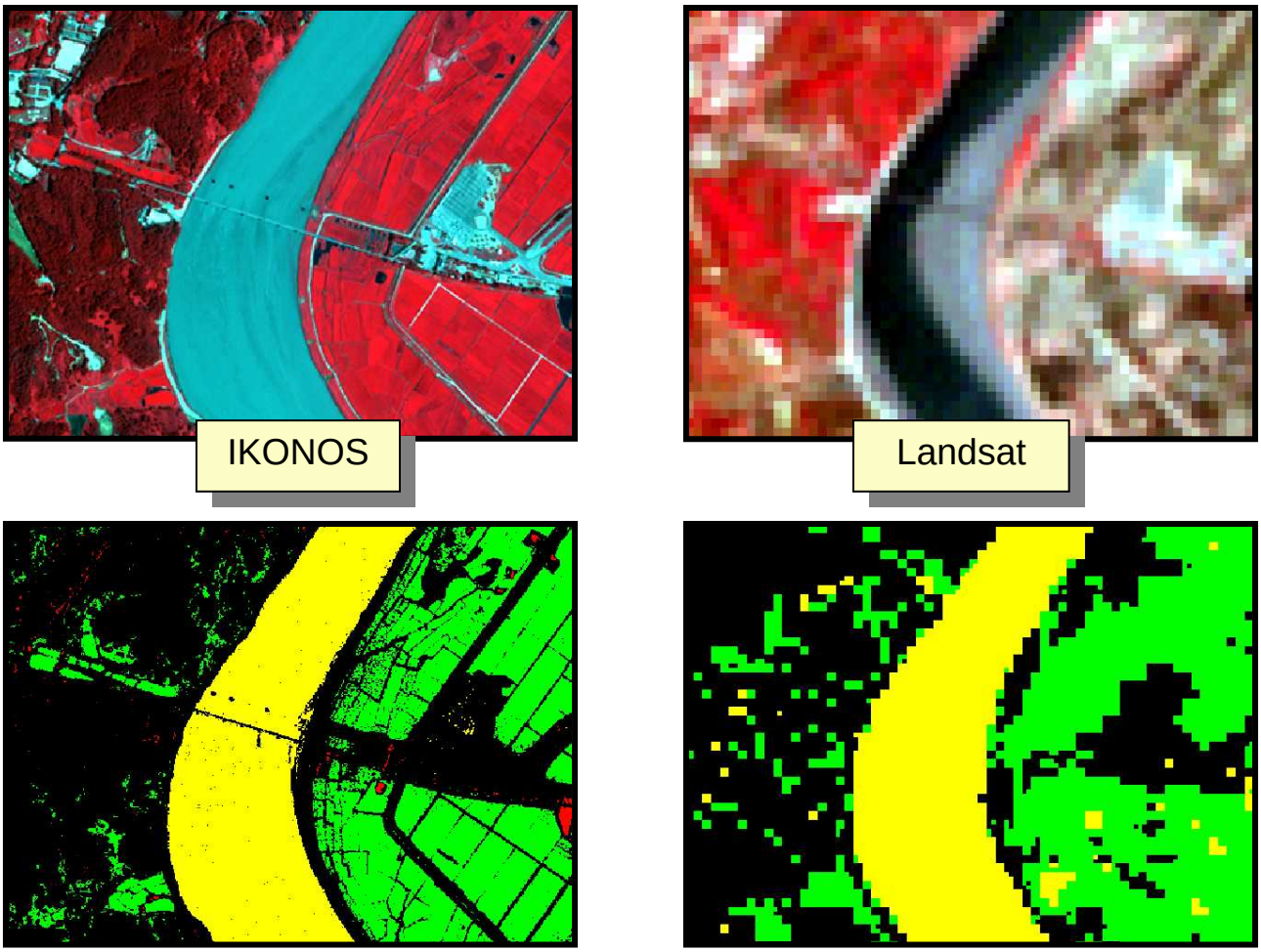


Figure 27. Space Imaging IKONOS and Landsat images (false color and classified) showing vector habitat and non-habitat areas. The difference in detail is due to the difference in resolution of the two images: IKONOS has 4-meter pixels and Landsat has 30-meter pixels. In the classification, river is shown in yellow, rice fields in green, irrigation ponds in red. Because irrigation ponds are small, they could not be classified on the Landsat image.

4.0 Survey-based and Statistical Evaluation of the SPD Program

In addition to the many examples provided in section 3.0, the impact of the SDP was also evaluated through user surveys and SDP-related statistics. The focus of the evaluation included overall contribution to Earth Science Enterprise research and effectiveness of the program.

The SDP program used several mechanisms to determine the types of research benefiting from SDP data. These mechanisms provided a means to evaluate the impact of the SDP program. The SDP evaluation comprised three primary components: an e-mail survey distributed to all SDP data recipients (**Appendix C**), Customer Feedback Letters (**Appendix B**), and SDP Data Use Statistics.

4.1 SDP E-mail Survey

An e-mail survey (shown in **Appendix C**) was sent to all SDP users that received SDP data. Qualified users were sent one e-mail survey regardless of the number of data requests they had submitted. A total of 252 surveys were distributed to SDP customers. Recipients were requested to respond to the e-mails within six weeks from receipt. The survey requested that the SDP user supply a brief summary of the impact of the data received, including data effectiveness and the data's role in future research or application, and a list of publications/presentations in which the SDP data played a role. The users were also asked to indicate any issues (technical, administrative, or other) that precluded effective use of the data received. From the 252 surveys disseminated, 93 responses were received, reflecting a 37 percent response rate.

4.1.1 Data Impact

In nearly all received responses, the data provided to the researchers by the SDP was either instrumental to the research being performed or supplemented data from other sources or sensors. Fifty-five percent of the responders expressed that SDP data "complemented existing projects." Forty-seven percent of the responders indicated that the SDP data "enhanced" projects that were already in progress. Thirty-four percent of the responders indicated that the SDP data they received was "invaluable, crucial and/or essential for their research." Additionally, the majority of respondents (69 percent) provided positive comments regarding data impact, included the following:

- 13 out of 93 researchers were "able to acquire data that would have been prohibitively expensive."
- 11 out of 93 users expressed a "significant decrease in time and effort required to collect spatial data."
- 7 out of 93 of researchers replied that SDP data provided a "cost-effective way of doing research."
- 5 out of 93 responders indicated that data was used in conjunction with some teaching facility.
- 28 out of 93 researchers suggested that, if available, SDP data would play a significant role in future research projects.

These responses demonstrate that the SDP data seems to have had a positive impact on the research being performed.

A limited number of negative comments were also received in response to the e-mail survey. Three survey responders claimed that the data they received had a negative impact on their work. One NASA researcher stated, "Space Imaging fell short of their advertised capabilities with respect to the product it was 'truly' able to offer." This comment was related to acquisition and delivery time and scene size. However, even with these misconceptions, this data was used for a separate project, and the work has been currently submitted for publication in a peer-reviewed journal. Additionally, two researchers were "not able to use the data as they intended." One researcher had hoped to use the digital elevation map derived by STAR-3*i*/Intermap for estimating ice slopes and roughness for the Bagley Ice Valley, for use in ICESat simulation studies; unfortunately the horizontal and vertical resolution of the STAR-3*i* was not sufficient for this application. Airborne laser measurements instead of radar measurements were requested, and perhaps this was the problem. However, this data was useful for another researcher who is involved with ice surface studies. For another researcher, scenes were ordered in fall of 1999 and not received until June 2000. By the time the data was received, project emphasis and interests had shifted. Fortunately, another department was able to use the scenes in several separate application projects. Nine other researchers also mentioned that because of the amount of time it took to receive the data, the images

could not be used as expected. Only two researchers had problems regarding the data rights restrictions, and only one researcher had a problem with the cloud cover on the imagery's point of interest.

4.1.2 Issues

Seventy-five percent of the responders to the e-mail surveys indicated that no issues precluded the effective use of the SDP data they received. The majority of the other 25 percent of the users stated that the amount of time it took to receive the SDP data (i.e., data acquisition to data receipt) hindered effective use of the data. Many of the latter respondents were involved in precision agriculture studies; crop conditions can change rapidly during the peak time of the growing season, and producers typically need to make management decisions (e.g., pesticide or nutrient applications) within 3-5 days following assessment of the crop's condition. Therefore, to maximize the utility of the imagery for making management decisions, shorter intervals between data collection and data receipt is paramount.

Another issue described by a small number of respondents was the data rights restrictions placed on the data. Several researchers felt that the data could be used more effectively if the data rights agreements did not prevent data transfer. Copyright restrictions prevented researchers from sharing scenes with other collaborators and in effect reduced the potential overall impact of the data.

4.2 Customer Feedback Letter

Responses to Customer Feedback Letters (**Appendix B**), which were distributed with each SDP data shipment, were also compiled and evaluated to help assess customer satisfaction. In the Customer Feedback Letter, the data recipient was asked to rate the quality of the data received, the experience with the individual vendors, the experience with the overall SDP process, the usefulness of the data, the effect the Data Rights agreement has on the utility of the data and/or the ability to accomplish research objectives, and finally to provide comments regarding process improvements and alternate data types that could benefit research. This information was maintained in a database and updated monthly to track customer satisfaction. The data recipients were also asked to provide a list of publications that have incorporated the use of SDP data. Of the 2835 data shipments distributed by the SDP, 436 feedback responses have been received for a 15 percent customer feedback response rate. The feedback responses reflect that on a scale of 1 to 10 (10 being the best), the average quality of the data received was rated at 8.7, the average data usefulness to the principal investigator was rated at 8.6, and the average overall experience with the SDP process was rated at 8.7. Also, the limitations of the data rights agreements on the data utility were rated on a scale from 1 (adverse effect) to 10 (no effect), and it was found that the average limitations of the data rights agreement were rated at 8.8.

4.3 SDP Statistics

SDP statistics that tracked tasking, data, and users were compiled over the life of the SDP. Regarding tasking, 106 DigitalGlobe/Intermap tasking requests, 46 Positive Systems tasking requests, and 663 Space Imaging tasking requests were reviewed and approved by a science tasking committee and subsequently completed (EarthSat products do not require tasking requests; these products are requested through the SDP archive). This represents a total of 815 tasking requests that have been reviewed, tasked, and delivered to Earth science researchers.

Figure 28 displays the current SDP archive holdings that represent the amount of data currently available in the SDP archive for each vendor. Approximately 25 terabytes (TB) of data were received from the SDP

vendors and were made available for ordering from the archive by NASA researchers. The geographic coverage of this data is shown in **Figure 29** and **Figure 30**. To date, 1067 orders have been requested from the SDP archive and have been completed and shipped to SDP researchers. It is important to note that the data requested from the SDP archive represents reuse of remote sensing imagery procured by NASA. A total of 2835 datasets have been distributed, either from the archive or to fulfill task requests, representing 31.3 TB of data shipped to science and application users through the SDP program. The SDP public Web site also contains unrestricted, compressed EarthSat mosaics that are available for download. To date, a total of 1,939,235 mosaics have been downloaded for a total downloaded volume of 77.77 TB.

As of September 1, 2003, 665 users from the science and applications communities affiliated with NASA have registered with the SDP. Of these registered users, 361 have received SDP data. The registered SDP users can generally be categorized by the following affiliations: university personnel, other U.S. government agencies, non-university NASA contractors, NASA (excluding SSC, which is shown separately), contractors to other U.S. government agencies, internal NASA SSC, and foreign. The distribution of registered users who have ordered data is shown in **Figure 31**.

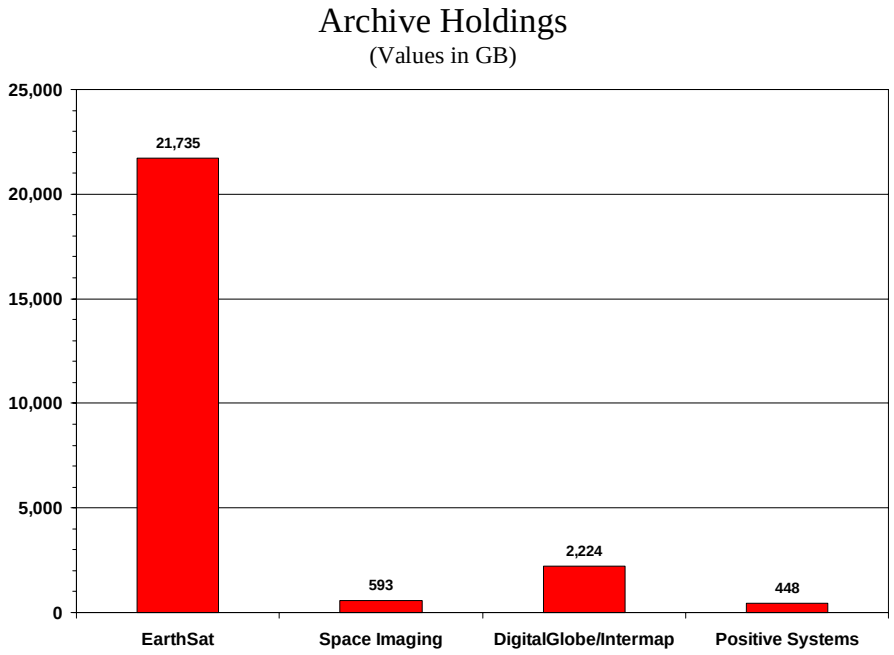


Figure 28. Amount of data currently available in the SDP archive as of September 1, 2003.

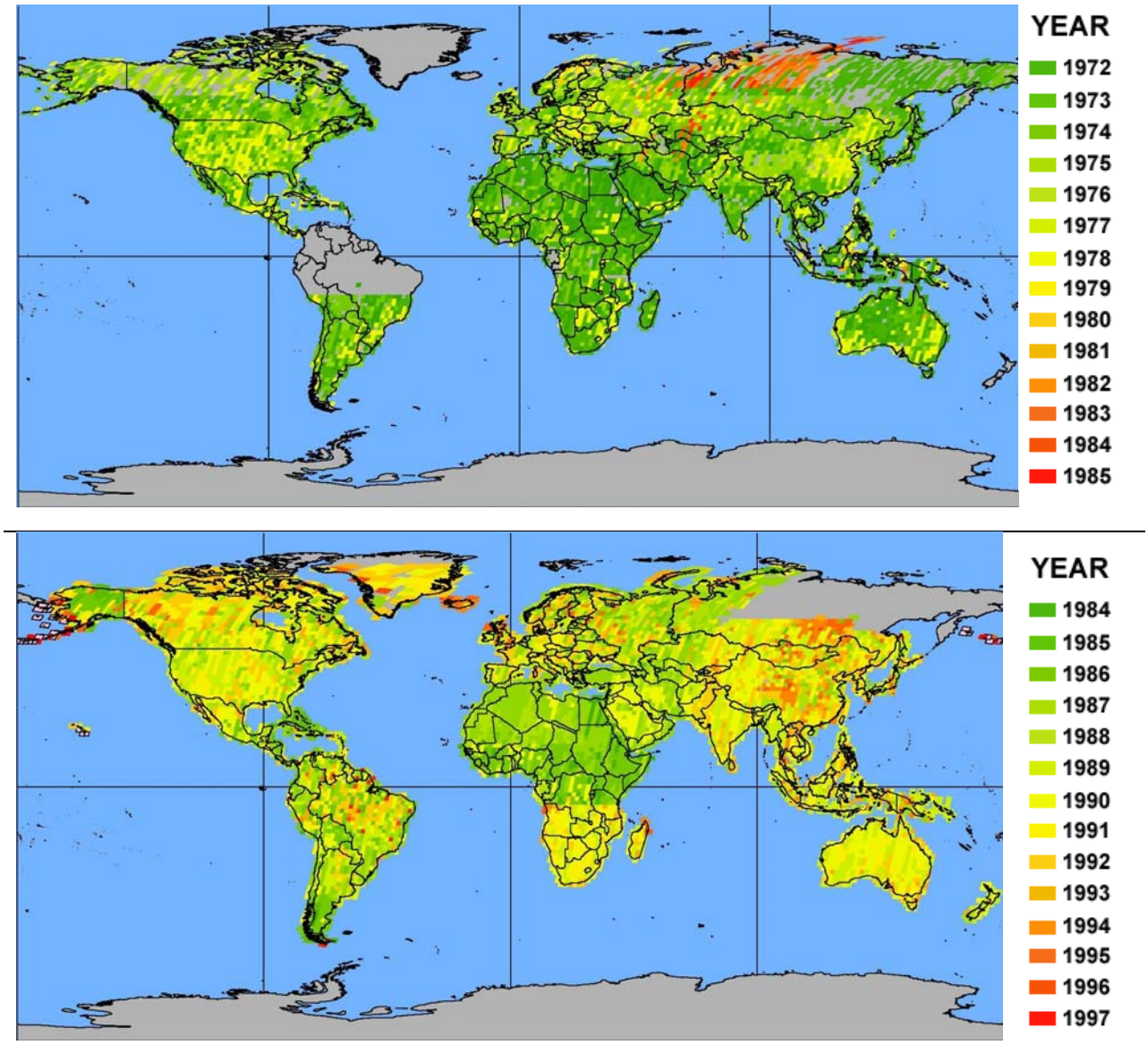


Figure 29. EarthSat global coverage MSS scenes (top) and TM scenes (bottom) purchased through the SDP and available in the SDP Archive. Areas that are not covered (i.e., gray) represent areas for which MSS or TM data could not be obtained.

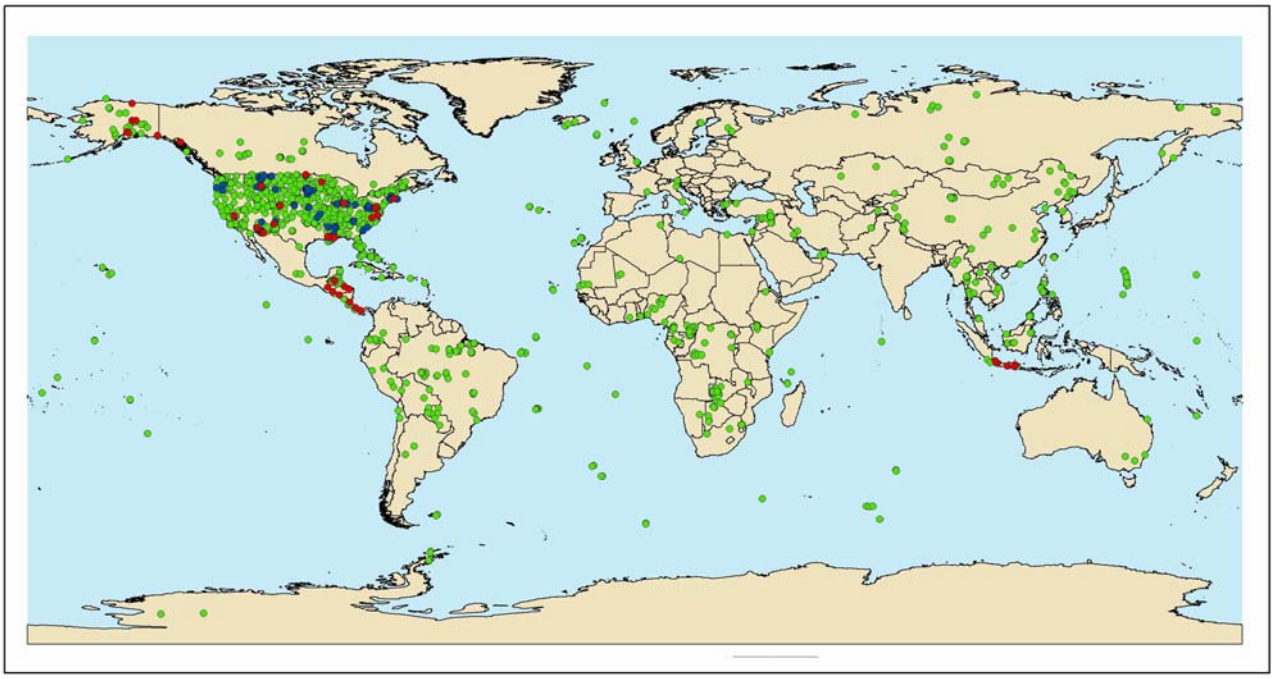


Figure 30. Locations of Space Imaging (green), Positive Systems (blue), and EarthWatch (red) tasks currently available in the SDP Image Archive (symbols are not indicative of the square kilometer area covered by acquisition).

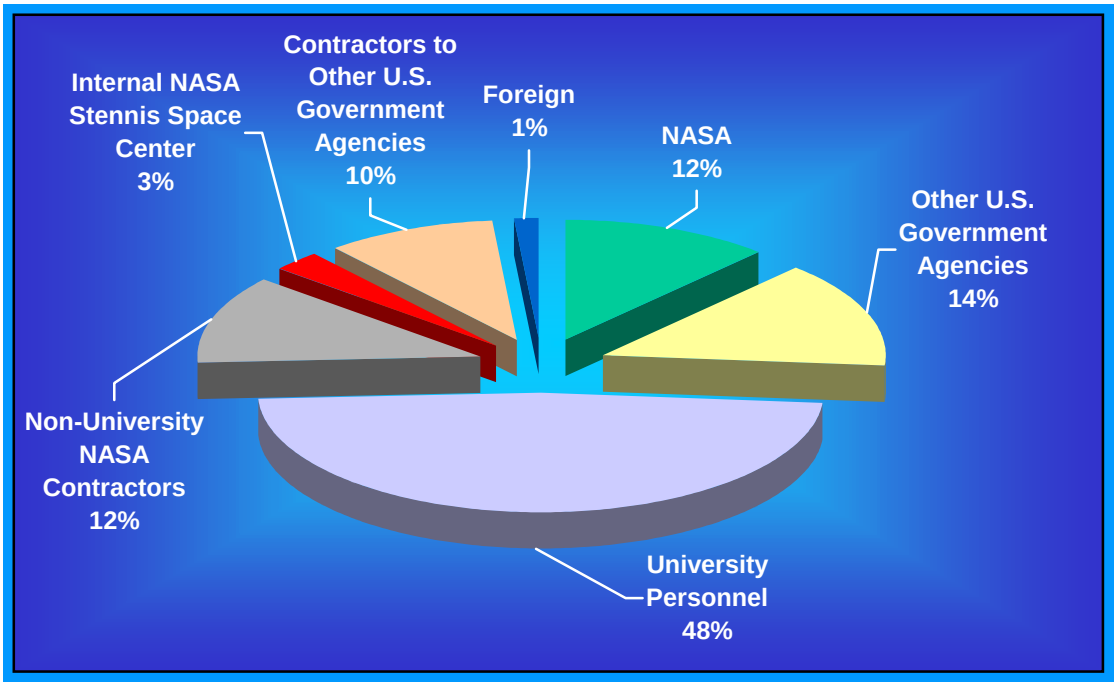


Figure 31. Percentage breakdown of the categories of SDP users who have ordered data from the Scientific Data Purchase program.

5.0 Lessons Learned

In many ways, the SDP represented an unprecedented partnership between NASA and commercial data providers. Many of the processes employed by the SDP were developed as needed as the program grew and evolved, resulting in lessons learned by both NASA and the data providers regarding commercial data and government/vendor/researcher interaction. Several of the lessons learned within the SDP program are similar to observations and recommendations made independently by the National Research Council (2002b).

5.1 Useful Data, Minimal Risk

The original goals of the SDP program were to obtain Earth science data from the private sector and to demonstrate that industry is willing to accept a majority of the precursory financial responsibility when providing this data. These goals have been met: the commercial sector can provide data while posing minimal risk to NASA, and the data products have proven to be useful to the science community.

With each SDP dataset delivered, NASA sent the participating scientists a questionnaire regarding the data usefulness and the quality of the service provided (Customer Feedback Letter, **Appendix C**). With a favorable response rate, the questionnaire indicated that almost all of the scientists advocated access to commercial data. The SDP data use, which reflected the MTPE science and applications categories, showed that the majority of users classify their research as Land Cover and Land Use (Science Research Category) or Resource Management (Applications Research Category), but the data also supported a broad spectrum of other research areas.

In many cases, the commercial sector becomes the sole source for providing certain types of remotely sensed data (e.g., high-spatial-resolution imagery from satellite and airborne LIDAR and IFSAR). Datasets such as those available from Space Imaging's IKONOS satellite open new opportunities for validating conclusions and conjectures derived from the government's coarser spatial resolution systems and for fine-scale feature extraction and virtual ground truthing. For the first time, phenomena inferred by spectral processing of coarse-resolution data can be validated by visual inspection with this high-spatial-resolution data. The National Research Council report (2002b) notes that as a result, the usefulness of the government's coarser resolution systems is increased.

Because several of NASA's SDP contracts are IDIQ contracts that require no precursory financial investment, the government has a means for purchasing only required data. Space Imaging's SDP contract enabled the NASA to purchase IKONOS data at a fraction of the cost associated with designing, constructing, and operating an asset like IKONOS; a similar system would cost millions of dollars. In addition, the SDP has pioneered the way for other data purchases, including POAM III, Ocean Winds, QuickBird 2, and OrbView-4 Warfighter hyperspectral (NASA data purchase contract canceled because of launch failure, at no cost to the government).

A cash-on-delivery data contract for unique data, especially prior to the system's being operational, does contain some risk for NASA, including the potential of not receiving the data and return of funds to the U.S. Treasury. This was the experience with the SDP contract with AstroVision. Because the company was not able to build and launch its system prior to the end of the life of the SDP contract, the contract was allowed to expire with no cost to NASA, and the associated funds were returned to the U.S. Treasury. The funds lost to NASA were $1.4 million, or 2.7 percent of the total SDP $50 million program. This may not seem to be a significant failure for an experimental program, particularly when considering that the

U.S. government as a whole did not incur any loss of funds. NASA may have been able to mitigate this risk with a thorough *expert* review of the company's business plan during the SDP proposal evaluation process.

While NASA did not lose any existing capability by not receiving the AstroVision data, the fields of natural hazards and disaster management research and applications were not able to benefit from this potential new source of Earth observation. This data source could potentially have benefited studies of hurricane development and tracking, thunderstorm development and tornado warning, fire monitoring and risk analysis, volcano event monitoring, coarse-scale monitoring of flood events, and cloud mapping for prioritization of other imaging events during emergency response activities.

5.2 Maturing Industry

Commercial remote sensing is a maturing industry. Customer service and product delivery time can be erratic, and saturation of tasking over an area of interest is unpredictable. Data specifications, minimum order sizes, and acquisition windows are also variables that are still evolving. In some cases, NASA discovered that delivered products did not meet contract data specifications. Following characterization, NASA opted to accept these products if they were deemed useful to the science community, because customizing commercial products for specific needs can lead to product delivery delays. The scientific community has a wide range of requirements, and the products that could have been rejected were still found to be useful. As a result, contract data specifications were changed to reflect the data's true performance.

5.3 Characterization

Commercial data products must be highly characterized. Unlike government-owned systems, commercial providers do not typically release detailed system descriptions because of competitive and propriety concerns. Consequently, the science community largely views commercial systems as "black boxes." This is a new paradigm for the NASA scientific community, which historically has had significant insight into sensor design and operation. Also, because commercial providers and the scientific community may have different system requirements and objectives, commercial providers may not necessarily characterize systems in the manner preferred by NASA researchers, necessitating independent data characterization. NASA has provided an independent characterization of each of the SDP data provider's datasets as discussed in Section 2.2.1. The National Research Council (2002b) reported that one of the most significant contributions of the government to the data purchase process has been data validation.

Partnerships have been found to facilitate the characterization process significantly. NASA and NIMA currently procure IKONOS imagery; the USGS is considering procuring IKONOS and other commercial imagery. By forming a JACIE team with NIMA, the USGS, and several university affiliates, NASA has capitalized on the groups' mutual interests. Each JACIE agency brings different strengths to the activity. This, in turn, reduces the cost of a full evaluation by minimizing duplication of government and industry efforts. This group provides a single government interface with Space Imaging that not only characterizes the IKONOS system but also obtains system information. This JACIE verification and validation team effort has resulted in updated radiometric calibration coefficients for IKONOS data. This update reflects coefficients obtained during a vicarious calibration efforts initiated by the JACIE team. Discussions between the JACIE team and Space Imaging led to the discovery that the IKONOS system compresses the datasets onboard the spacecraft; however, the lossy compression has had a minimal impact on the research, because the 11-bit data provides an increased dynamic range. Another discovery was that Space

Imaging uses a digital image restoration technique called Modulation Transfer Function Compensation (MTFC). The effect of this process has been investigated by NASA and presented to the scientific community. JACIE team investigations also discovered that Space Imaging incorrectly applied the MTFC algorithm, or kernel, creating overcompensation in the image cross-track direction and an undercompensation in the along-track direction. Space Imaging subsequently rotated the MTFC kernel to correct the error. Space Imaging validation findings were reviewed and shared with the scientific community during the High Spatial Resolution Commercial Imagery workshops held in March 2001, March 2002, and May 2003. With this workshop, JACIE fulfilled a recommendation from the National Research Council report (2002b) of "facilitating direct communication between members of the scientific community and the private sector." NIMA also was instrumental in revealing an error in the block adjustment of IKONOS images. This error was investigated by Space Imaging and subsequently corrected. Additionally, the USGS evaluated DEMs produced from IKONOS stereo pairs and found that in some cases, the vertical accuracy of the DEMs was worse than what was expected (i.e., the accuracy exceeded the expected error limit). As a result, Space Imaging modified its DEM production procedures. This positive interface between the JACIE team and Space Imaging lead to production of a higher quality product by Space Imaging.

Several commercial companies have proposed to emulate the NASA characterization process. This could result in having systems characterized according to NASA's preferences; however, independent assessments may become difficult because of the extremely small validation community. Only a small number of experts exist in this area, and many of these experts use very similar validation methods. NASA should begin research and development of alternative validation approaches to ensure continued independent characterization.

5.4 Centralized Management Organization

The existence of a centralized organization for the administration and management of the SDP greatly facilitated the effectiveness of the program. The SDP functions much like a typical NASA mission in that it has tasking, verification and validation, data distribution, and data archiving components. In addition, the SDP also must manage the complexities of commercial IDIQ contracting, continual product deliveries, and vendor invoicing/payment. All of these functions were performed and/or coordinated at SSC.

Several benefits resulted from the centralization of these functions. First, because SSC performed contract management and coordinated science tasking, SSC served as the interface to both the science community and the SDP companies. Thus, ESE scientists did not have to implement individual data purchase contracts or handle contracting issues. Likewise, the SDP companies did not have to interact with hundreds of science investigators. In most cases, SSC served as the interface between science investigators and data vendors to resolve issues concerning tasking and questions about SDP data. Some direct company-scientist interactions occurred when it was more efficient to do so. One opinion expressed by the National Research Council (2002b) was that direct company-scientist interactions were more effective with a government agency acting as mediator. Centralized data receiving, delivery verification, and data archiving greatly facilitated NASA's independent data characterization effort. The SSC characterization team had access to all SDP data for evaluation purposes, which gave the team the ability evaluate problems. In many cases, scientists were able to consult with SSC personnel, who understood the impact of data quality issues on science research.

The centralized functions, science and industry interactions, and independent characterization efforts allowed SSC to gain significant insight, rather than oversight, into the commercial sector and to share this

insight appropriately with the science community. This process has increased confidence in the commercial sector's ability to meet science needs.

5.5 Export Control, Data Licensing, Data Archival, and Tasking Prioritization

Understanding issues regarding export control, data rights, and long-term archival is crucial to successful commercial data purchases. The types of data distributed through the SDP require up-front commodity classification to determine International Traffic in Arms Regulations (ITAR) applicability. ITAR issues associated with Intermap's STAR-3*i* data initially caused delays in data delivery to scientists. In 2002, Intermap Technologies contested the State Department's decision to regard STAR-3*i* data as ITAR controlled and was successful in having this decision changed. Now only the sensor itself and some of the processing software is controlled. Export control issues should be addressed early in any future data purchase efforts.

The SDP contract provision for data licensing allowed data distribution within the NASA ESE affiliated science community but did not permit free and open distribution for the general public. Free and open data distribution policies are not typically well received by commercial industry. This issue was heavily debated early in the SDP program and is listed as a concern in the National Research Council report (2002b). There was great concern that the majority of the data purchased through the SDP would not ever become part of the nation's global archive—a valuable resource for gaining knowledge about the Earth and how it is changing. Additionally, some scientists have requested access to raw data and intermediate products, which most vendors are reluctant to supply because of competitive concerns. In the future, special contract negotiations and pricing arrangements will likely be required to provide appropriate data licensing that better addresses science needs. The significance of long-term data archiving and distribution was somewhat underestimated in the SDP. At the conclusion of the SDP, approximately 25 TB of data exists in the SDP archive, and approximately 31.3 TB have been distributed to science users. Much of this archived data is still desired by NASA researchers. Thus, data archiving and distribution functions are still ongoing, even though the SDP program has, in essence, come to an end. Additionally, because of data licensing provisions, access to the majority of the SDP data must be limited to NASA-affiliated researchers only (the exception is EarthSat, whose data products can be distributed freely to the general public). This creates an additional step in the distribution process to verify that those requesting data are affiliated with NASA's ESE. In future data purchases, funding for long-term archiving and distribution must be allocated to maximize the long-term utility and value of the data. Future licensing of data should also incorporate "sunset clauses" to allow data to revert to public archive after a certain amount of time has passed. The National Research Council (2002b) also discussed the need for long-term archival of data purchased through the SDP for use in change detection studies. Tasking prioritization under the SDP contracts lacked definition. In many instances, the government's tasking requests were in competition with the requests of the vendor's many other commercial customers. As a result, verification and validation acquisitions and other special collections requiring a very small acquisition window were not easily obtained. The National Research Council (2002b) noted that SDP tasks were often given lower priority than were the vendors' other commercial tasks. In addition, tasking status information was often not made available to customers. In the future, customers may be required to negotiate tasking priorities and associated pricing prior to submitting tasking requests.

6.0 Summary and Challenges

Through the Scientific Data Purchase program, NASA has provided affiliated ESE research scientists with high-quality remote sensing data with which they have enhanced and advanced their Earth science

studies. The data has proven to be invaluable to many of the recipients and has had significant impact on many projects as evidenced through publications and presentations. NASA provided this data to its Earth scientists at a reduced risk and cost to the government when compared to traditional government-build approaches. Through evaluation of the SDP process, several critical lessons were learned: (1) SDP data has proven itself very useful to NASA scientists, (2) the commercial remote sensing industry is maturing, (3) independent characterization as well as verification and validation is critically important, and strategic partnerships can facilitate such characterization, (4) a centralized organization for management and for verification and validation are very beneficial, and (5) issues such as licensing and data archival are critical to the success of a data purchase effort.

Following the initiation of the SDP, the Commercial Space Act of 1998 (U.S. House, 1998), Public Law 105-303, was enacted to encourage the development of the United States' commercial space industry. Part of this legislation required that "NASA, and where appropriate, other Federal agencies and scientific researchers, acquire, where cost-effective, space-based and airborne Earth remote sensing data, services, distribution, and applications from a commercial provider." Thus, if the commercial sector can provide data that is deemed worthwhile to the NASA science community, NASA must purchase this data commercially. In addition, the U.S. Commercial Remote Sensing Policy released in April 2003 has directed the U.S. government to consider using spaceborne commercial remote sensing capabilities, to the maximum reasonable extent, to satisfy its imagery and geospatial needs (OSTP, 2003). However, several challenges face NASA and other government agencies interested in implementing remote sensing data purchase programs.

For instance, NASA and other government agencies must define a method to make commercial data and data products regularly available. The Scientific Data Purchase program was the result of a Congressional directive to NASA to procure $50 million of remote sensing data (U.S. Senate, 1996). This directive was followed by a similar Congressionally mandated $20 million data purchase effort in 2001 (U.S. House, 2000). Once the 2001 data purchase is complete, no NASA contracts to purchase commercial remote sensing products will exist. Scientists interested in using commercial data in their research will be required to purchase products on their own through direct interaction with a vendor.

A related issue is the identification and selection of the types of data that should be purchased. In the SDP, a wide net was cast across the entire private sector, allowing companies to propose products they perceived as potentially valuable to Earth science research. This approach allowed a NASA science panel to evaluate and select those products having the greatest potential benefit to Earth science. Evaluation of the available commercial data products against a set of NASA Earth science and applications needs is essential. In addition, systematic studies of data requirements for various research and applications would be extremely beneficial in comparing research needs with commercial data specifications.

Another major challenge is identifying the funding required to purchase commercial data on an ongoing basis. The SDP has provided data at no cost to NASA project scientists. The availability of remotely sensed data augmented many projects; some projects require additional data to complete the research, but funding is not available. Were it not for the SDP, the prohibitive cost of the imagery might have prevented certain projects from developing, as few researchers have the funding necessary to purchase required datasets. The National Research Council (2002b) also noted that many scientists do not have the resources necessary to purchase commercial data. The lack of successive funding for new data acquisitions has interrupted the progress of many projects. If it is determined, based on this report and/or other information, that commercial data has value to the NASA science community, then associated funding requirements and a means to budget for future data procurements should be addressed. Currently, NASA's approach to addressing this issue is to permit scientists responding to NASA Research

Announcements to propose use of commercial remotely sensed data as part of their NASA research proposal and to include the costs of such data in their corresponding cost proposals.

Data policy and licensing issues are a significant challenge that must also be addressed. In a majority of NASA data purchase contracts, licensing provisions permitted free distribution within the NASA-affiliated research community. This restriction is in contrast to the free and open distribution policy of most government-operated systems, thus creating limitations on research utility for some researchers. Free and open distribution, while potentially providing increased marketing for the private sector, may also impact data resale value. The National Research Council (2002b) suggested that the government should negotiate not only for open distribution rights but also for the data providers to reduce the cost of older datasets for science researchers. Sharing of data between government agencies must also be considered.

7.0 Conclusions and Recommendations

The SDP has successfully demonstrated a new way of doing business and has achieved the original program goals of obtaining Earth science data from the private sector and of demonstrating that industry is willing to accept the majority of up-front financial responsibility when providing data to the government. However, as is pointed out in the National Research Council's report (2002b), data purchase programs are still maturing. By evaluating this program, assessing the strengths and weaknesses, applying the lessons learned, and addressing remaining challenges, NASA and its commercial partners can expand the resources available to the ESE community in its quest for knowledge about the Earth and its changing environment.

This evaluation was conducted by NASA's Earth Science Applications Directorate at Stennis Space Center, the organization responsible for implementation and administration of the Scientific Data Purchase. Although this assessment attempted to evaluate the SDP in an objective manner, a more thorough and independent review is needed. It is recommended that an independent review team conduct an additional review of the SDP. The National Research Council (2002b) also recommends a thorough, independent review of the SDP. This review should include (1) a thorough assessment of the scientific impact of the SDP by a qualified science team, (2) an industry analysis to understand the benefits and issues experienced by the SDP vendors, and (3) an assessment of the SDP management processes, including contracting, administration, tasking, verification and validation, distribution, and archiving.

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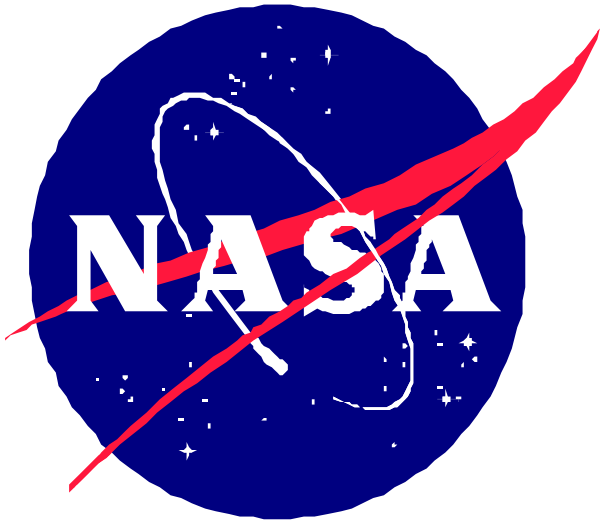

RFO-13-SSC-O-97-21
ATTACHMENT 2: Technical Requirements

MTPE Scientific Data Buy Program

Phase I

Table of Contents

1. Introduction

This solicitation is the first phase of a two phase program to qualify and purchase data sets or products for the Mission to Planet Earth (MTPE). MTPE seeks data sets which will provide critical new science measurements or more cost effective ways of extending the current Earth Observation System (EOS) data sets.

The overall science goal of MTPE is to provide long-term understanding of the Earth system needed to protect our global environment for current and future generations. The results of MTPE are essential to the broader national goals for a sustainable America (PCSD, 1996). The United States, through the U.S. Global Change Research Program (USGCRP), along with other nations, supports the research needed to characterize and understand interactions between localities and global change. Global change research provides fundamental knowledge leading to increased efficiency in the use of natural resources and improved prediction of weather and climate. The application of scientific knowledge significantly enhances the relevance of the MTPE program to critical issues of sustainable development.

2. Background

NASA is exploring new ways of doing business that will result in faster, better, and cheaper methods for achieving scientific research results. The Administration supports such efforts and, to encourage use of relevant private sector capabilities, the President's Space Policy directs NASA to establish a demonstration program to purchase data products from the private sector. Accordingly, $50 million was proposed for a data purchase in the NASA FY 1997 budget and Congress included this amount in NASA's 1997 budget appropriation. In addition to obtaining important MTPE data sets/products, the demonstration program will enable NASA to better assess the willingness of industry to accept a major portion of the up-front financial risk associated with this effort and its ability to provide useful data products in a cost-effective and timely manner.

3. Purpose

The science requirements identified in this solicitation address key uncertainties about the national and global environmental changes and the Earth system. The purpose of this Request for Offer (RFO) is to acquire scientific information that will support research themes identified in section 5, Attachment 2.

This data purchase solicitation seeks to augment and extend the EOS measurement sets through contracts to purchase data that private sector participants identify as meeting critical elements of the science goals of the MTPE Program and that these participants agree to develop and deliver on a "cash on delivery" (COD) basis. This program is not intended to fund any research activities directly but to provide data sets or products for use in research activities funded within MTPE.

In issuing this solicitation, the Government is attempting to obtain the maximum value for its investment of taxpayer dollars by challenging the private sector to create and sell necessary scientific data sets or products with no Government oversight. This process may involve additional risk to the data providers because the Government will not provide development funding for these data sets or products. NASA has attempted to minimize this risk with a two-phase approach developed for this solicitation. The Government also recognizes that this procurement approach will significantly change the scope of the offeror's activities because it will be the specific responsibility of the offerors to define the linkages and

value of their proposed products to the proposed science issue for which the data will be used. In summation, this solicitation is intended to demonstrate the effective integration of the requirements of the scientific community and capabilities of the U.S. remote sensing industry.

The Government believes that this solicitation is especially timely due to the increasingly close relationship between (1) its Earth-focused scientific data needs, and (2) the increasing interest of the private sector in developing satellite and other systems that provide data relevant to management of the Earth's resources. It is anticipated that this approach will also shorten the time between inception and application to practical problem solving and routine operations.

4. Program Approach

This data purchase will be completed in two phases under separate contracts. Figure 1 depicts this two-phase process. A two-phase approach makes it possible to evaluate the critical characteristics and value of the proposed data before actually committing to additional specific data purchases. Funding for phase I and II of this program is currently $50 million. Upon successful completion of phase I (the delivery of scientifically acceptable and validated simulated or prototype data sets), the offeror qualifies for phase II (production) purchases. **Those qualified phase I products whose phase II purchase would exceed the $50M may be candidates for funding from other MTPE programs under this solicitation.** The qualification of phase I data sets or products does not constitute a commitment from the Government for any additional purchases of data sets or products.

4.1 Phase I

In the first phase, prospective data providers are requested to submit proposals identifying data sets or products that address the scientific requirements outlined in section 5, Attachment 2. These proposals will be evaluated against the science, price, and performance characteristics in addendum 3. If the phase I proposal is accepted, NASA and the offeror will negotiate the period of performance (up to 6 months), price, delivery schedule, validation plan, and data rights for the products to be delivered. The data delivered under phase I can be simulated or prototypical data sets or products. Upon receipt of these deliverables described in Block 20 of the SF 1449 and the Continuation Sheet to the SF 1449, the data provider will be paid and a 2- to 4-month evaluation and validation period will begin. The data will be validated by the Commercial Remote Sensing Program Office at Stennis Space Center (SSC) in cooperation with a MTPE science team and the data provider. This validation process will ensure that the delivered product meets the data specifications provided in the phase I proposal. It will be the offeror's responsibility to determine to which of the MTPE science themes their data are applicable. If it is determined that a data set or product submitted will not meet the scientific requirements or does not meet the proposed specifications, additional data will not be purchased from the data provider and the data provider will not be a participant in phase II of this requirement. The duration of phase I and entry into phase II will be determined on an individual contract basis to minimize the latency between phases.

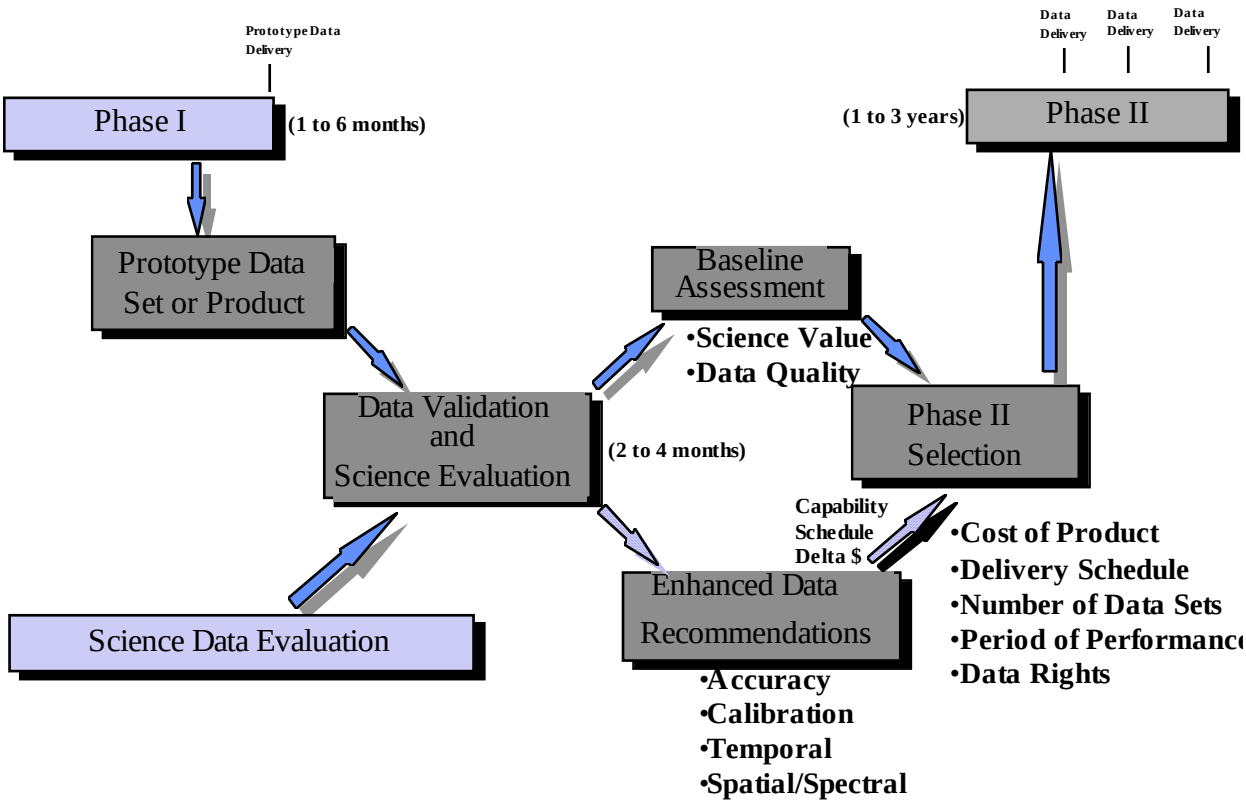

Figure 1. Two-phase data purchase process.

Once the data have been evaluated by the MTPE science team and validated at SSC, the evaluation and validation team will submit an evaluation report summarizing the science value of the data sets or products. In addition, where it appears that relatively minor improvements would make the initial products scientifically valuable or would significantly increase the value of acceptable products, the MTPE science team will provide recommendations for potential enhancements to the data. This information will be provided to the data provider for consideration. If a phase II solicitation is issued, the data provider then has the option of offering the enhanced data set/ product or offering the baseline data proposed in phase I. After submitting a phase II proposal, a commitment on future data sets or products will be negotiated and integrated into the MTPE research activities.

For phase I, NASA intends to make multiple data buy awards of up to $500,000 for data sets and data products to be delivered over a defined time period. NASA reserves the right to make no awards should it find that none of the proposals meets the needs of the MTPE science teams or provides best value to the Government.

4.2 Phase II

The second phase of the data purchase solicitation will consist of contracts between the Government and those data providers that have successfully completed the first phase of the solicitation process and have provided data that have been determined by the science evaluation team to be of value to the MTPE

program. A letter RFO describing the quantity of data, delivery dates, data characteristics (baseline or enhanced) and the performance period will be issued to the data provider. Specific data sources will then be selected to enter into contracts of 1 to 3 years.

4.3 Optional Offers

As part of the new way of doing business, NASA plans to use approaches similar to the MTPE Scientific Data Buy whenever it is within the ability of industry to respond to and accept the terms and conditions offered. Recognizing the pathfinding nature of this MTPE Scientific Data Buy, NASA will consider optional offers that exceed the existing $50M budget if the offeror accepts the terms and conditions provided in this solicitation and the offer provides the best value to the Government in executing the MTPE program. If selected, funding for these optional offers will be provided by augmenting the existing $50m budget prior to phase II contract awards. Optional offers will be evaluated and subject to the same terms and conditions as other offers under this solicitation. The Government, at its option, may unilaterally determine not to pursue optional offers and will so notify offerors during the phase I process. Consideration of optional offers will be contingent upon the availability of funds.

5. Science Requirements

5.1 Science Research Themes

This solicitation offers a new challenge to the remote sensing data acquisition and delivery community. Potential data providers must understand the scientific goals of NASA's MTPE program sufficiently to identify what scientific data they may provide that will not only fulfill the science themes of research but will also be cost effective. NASA is not requesting that the data provider community solve the scientific problems of MTPE, but rather that the community deliver the data sets and products, which provide scientific measurements over a specific area, a specific region, or the entire Earth for specific time periods.

Requirements for the data to be provided under this solicitation are based upon the Mission to Planet Earth Science Research Plan, V.1, September 1996, which contains NASA's research plans and data needs. This document should be consulted to understand the science program and the characteristics of its data requirements.

The science program contains five major program elements (science themes):

1) Land-Cover and Land-Use Change Research

2) Seasonal-to-Interannual Climate Variability and Prediction

3) Natural Hazards Research and Applications

4) Long-Term Climate: Natural Variability and Change Research

5) Atmospheric Ozone Research

The research plans presented in the above-noted report are deliberately broad, while providing overall direction and scope, to enable the programs to grow and evolve through time. To add specificity, some data criteria have been developed for this solicitation. Table 1 provides data set types that have been identified as being of the greatest value to each science theme. A more complete explanation of each science theme and the high priority data set types is provided in Appendix A.

Table 1. Critical Data Sets

Science Area	Data Set or Product Use
Land-Cover and Land-Use Change Research	1) Quantify past, present, and future land-cover and land-use patterns at regional and global scales 2) Understand natural and human-induced influences that lead to changes in land cover, land use, and marine ecosystems 3) Support scientific requirements of the National Environmental Monitoring and Research 4) Support design of a prototype environmental report on trends in and the status of the U.S. environment 5) Improve methods for the sustainable management of farmlands, forests, rangelands, and coastal marine resources
Seasonal-to-Interannual Climate Variability and Prediction	6) Measure globally distributed atmospheric wind profiles 7) Provide atmospheric sounding for weather and climate prediction
Natural Hazards and Research and Applications	8) Improve methods and understanding of how to best characterize and mitigate the consequences of natural hazards for both managed and natural ecosystems
Long Term Climate: Natural Variability and Change Research	9) Test the utility of new measurements to meet the continuity requirements of the EOS science program

5.2 EOS Measurement Continuity Test Sets

NASA is currently conducting a biennial review of MTPE to determine how best to provide continuity in the EOS science measurement areas needed to meet the MTPE and EOS science objectives. A component of the review is to determine the best means to acquire data in the key measurement areas after the predicted lifetime of the first EOS satellites (2004 or soon thereafter). These studies are also examining the possibility of obtaining the data for these measurements from smaller instruments and thus smaller and cheaper satellites and launch vehicles. Because the scientific requirement of follow-on measurements is to be qualitatively the equivalent of the first series of EOS instruments, NASA is very interested in buying data from new sensors concurrently with the first EOS series to evaluate whether these new sources of data sets can replace the first series of EOS sensors. The current measurement areas, the instruments that provide key measurements in those areas, and the satellites on which they will fly are provided in Table 1, Appendix A. Further information on these instrument characteristics and detailed descriptions of their data products can be found in the MTPE Reference Handbook.

Generally, the criteria for replacements to existing or planned EOS data sets are as follows:

- In order for a "replacement" data product to be "qualitatively" equivalent to a current measurement, it must meet established requirements for validation, timeliness, and spatial scale, because it will be compared against data sets already well defined by a working science team, possibly involving continuity with a precursor data set.

- The proposed data set may be a continuation data set from an instrument which has flown or may be a new data set that qualitatively matches one of the products currently defined in the MTPE program. A data set where a phase C/D contract (or equivalent) has been awarded for an instrument or produced under an international memorandum of understanding will not be considered.

- The data set may be produced by an instrument designed under MTPE or another program. The offeror may make any arrangements for flying the instrument that produces the data set on a U.S. Government spacecraft (as long as full-cost reimbursement is made to the Government). The requirement is for functional equivalence of the data that is or that can be produced. Burden of proof lies with the offeror.

5.3 Other Considerations

5.3.1 Integrated Data Sets

As noted in the MTPE Science Research Plan, Earth science problems are complex and are seldom capable of being fully understood from the data of a single sensor. Thus the development of integrated data sets is of great interest to the science program. While the intent of this solicitation is to purchase data products primarily derived from satellite data, it is of special interest for the purposes of this procurement to take maximum advantage, when it benefits the science objectives, of the increasing capabilities for integrating disparate data sets (i.e., radar and optical; 1-meter and 30-meter resolution; panchromatic and multispectral; and ground, aircraft and satellite observations).

5.3.2 Duration and Spatial Coverage

The scope and amount of the data to be offered can vary widely, from regional to global in spatial coverage and in duration from months to years to decades. The coverage will be determined by the requirements of the science problem being addressed. However, the temporal coverage has additional constraints imposed by both the limited funding level and the finite duration of the present solicitation. These limits will require that the offeror's price proposes long-duration data streams on the basis of delivering data for an initial period that fits within the present $50 million budget for all selected data sets and data distribution support with price quotations for additional purchase periods.

The data provider should also note that while the major thrust of the U.S. Global Change Research Program requires the measurement of change over multiple decades, shorter time series (months to several years) will be needed for two purposes. One, the data sets created to demonstrate that data from a new sensor can be used to continue the measurements of current EOS science parameters seamlessly and two, the data required to support a time-limited science campaign or to support an Earth system process investigation. Validation of a new sensor system technology to continue the collection of EOS is as important as the collection of new data set types.

5.3.3 Calibration

Most of the scientific uses of the satellite data require comparison with other data sources, including other satellite sources, aircraft, and ground measurement. An important consideration is that the comparisons with other data sets must be made over extended periods of time lasting years to decades. This requirement makes calibration and validation of the science products of prime importance. Calibration must be maintained at a suitable level for the expected variations in the phenomena being measured. The data provider is expected to perform calibration and validation sufficient for the science problem that will be addressed by their data.

6. Other Sources of Information

Additional information on the MTPE and EOS program can be found in the following documentation and NASA World Wide Web sites:

- NASA Mission to Planet Earth Science Research Plan, (1996) R. Harriss et al.

  http://www.hq.nasa.gov/office/mtpe/visions/visions.html

- Mission to Planet Earth/Earth Observing System Reference Handbook, (1995) G. Asrar and R. Greenstone. http://www.hq.nasa.gov/office/mtpe/education/education.html

- Science Strategy for the Earth Observing System, (1994) G. Asrar and J. Dozier.

http://www.hq.nasa.gov/office/mtpe/education/education.html

- NASA MTPE Home Page: http://www.hq.nasa.gov/office/mtpe

- EOS Project Office Home Page: http://spso.gsfc.nasa.gov/spso_homepage.html

- MTPE Commercial Strategy, March 1997. http://www.hq.nasa.gov/office/mtpe/visions/visions.html

7. Validation Plan

See Addendum No. 1, Instructions to Offers, for instructions regarding the validation plan.

8. Intellectual Property Rights Data and Data Products

As part of the phase I offers, the data provider will discuss data rights provisions as delineated in Addendum No. 1.

9. Best Value Characteristics

Offers submitted in response to this NASA RFO will be judged on two sets of best-value characteristics as provided in Addendum 3 of the RFO.

10. Deliverables

Deliverables are delineated in Block 20 of the SF 1449, as further described in the Continuation to SF 1449.

Appendix A

SCIENTIFIC RESEARCH THEMES

FOR THE

MTPE SCIENTIFIC DATA BUY

BACKGROUND

The following paragraphs identify high priority scientific issues which must be resolved to achieve the goals of the U.S. Global Change Research Program, National Science and Technology Council Committee on Natural Resources and the Environment, and President's Council on Sustainable Development. The questions are broadly defined to allow Offerors to fully define the most creative pathways to appropriate data sets. It is expected that proposed data will be derived from a combination of new sources, and through unique methods of data fusion using existing data.

SCIENCE AREA: Land-Cover and Land-Use Change Research

Changes in land cover and land use are poorly documented and understood in the U.S. and around the world. This problem is especially acute in many coastal areas where population and commerce are concentrated. The MTPE and USGCRP are implementing the Earth Observation System (EOS) to provide global information on changes in terrestrial and coastal ecosystems at relatively low spatial resolution. A significant gap in the current design for acquiring scientific information is a comprehensive assessment of how natural and human-related driving forces of environmental change are expressed as a function of both spatial and temporal scales. Episodic, intense forces operating at local-to-regional scales at many places around the nation and the globe can have an important cumulative influence on global change. It is also clear that the most important human consequences of environmental change occur at local scales. Urbanization and agriculture are two major drivers of environmental change. Efforts to sustain the ecological and environmental goods and services, that are required to support continuing economic progress, will require understanding of natural resource dynamics at local scales to support both scientific research and the development of improved resource management tools and methods. The following data and scientific information are required to provide researchers with an improved basis for understanding, assessing, predicting, and responding to the causes and consequences of changes in terrestrial and coastal marine ecosystems from natural and human-related influences:

1. Quantify the past, current and future land cover and land use patterns at regional and global scales:

The USGCRP has a continuing effort to monitor and inventory the current land cover of the Earth at 1-km spatial resolution. MTPE currently sponsors some research on land cover change at finer spatial resolutions. MTPE seeks scientific data products to enhance research on new and improved methods for measuring and land cover and land use change. The information required will most likely come from the development of new remote sensing technologies, or from unique methods of data fusion applied to existing data. There is currently no comprehensive, systematic effort to synthesize a state-of-the-art data base on land cover, land use, and shoreline change for North America. There are also significant limitations in scientific understanding of how best to combine existing data, or specify future data requirements, to quantitatively document changes in critical ecosystem characteristics. For example, what spectral, spatial, and temporal sampling is necessary to document land cover and land use changes in complex multi-use landscapes typical of North America? How can existing or new data from ground-based, airborne, and/or satellite sources be integrated to provide the basis for research on the design of a world crop monitoring system, a forest monitoring system, or a shoreline monitoring system? What level of spectral, spatial, and temporal resolution is necessary to provide accurate documentation of stress or changes in specific local habitats which are important to the maintenance of environmental quality or biodiversity (e.g., wetlands, floodplains, groundwater recharge areas, etc.)? MTPE seeks data products that would document land cover change in the U.S. (including Alaska) over the last three decades at a spatial resolution that approximates Landsat, or better. The databases provided might result from the fusion and/or analysis of data from many sources including recently declassified intelligence satellite photographs, Landsat, synthetic aperture radar, aircraft remote sensing, and a variety of in situ measurements. A validation plan must be part of the proposal.

2. Understand natural and human-induced influences that lead to changes in land cover, land use, shorelines, or terrestrial and marine ecosystems through integration of remote sensing and socioeconomic data.

The magnitude, spatial scale, and pace of land cover and land use change may have accelerated over the past several centuries. Gaining a better understanding of the factors that determine land cover, land use, and terrestrial and marine ecosystem change is a priority concern of the global change research community. A primary challenge in this area of study is the integration of remote sensing data with socioeconomic data. The MTPE program seeks scientific data products which will enhance scientific research on the prediction of the sensitivity, vulnerability, and resilience of ecosystems to natural and human-induced change. This scientific information should be especially useful for local and regional areas where there are indications of a conflict between economic development goals and the sustainability of natural resources. It is expected that scientific information necessary to enhance research on these issues will require the integration and fusion of multiple data sources in a geographic information system (GIS). New sources of remote sensing data from airborne or satellite platforms are also likely to make a contribution to these issues by providing unique spectral, spatial, or temporal information. The data provider should clearly specify how the products proposed will address the challenge of determining linkages between human activities and changes in terrestrial and marine environments. Products may result from a new, innovative measurement technology, or be the result of unique methods for combining existing in situ and remote sensing data through data fusion. Offerors should not duplicate any of the data sets available at the NASA Socioeconomic Data and Applications Center address (http://sedac.ciesin.org).

3. Support the Scientific Information Requirements for National Environmental Monitoring and Research.

The Office of Science and Technology Policy is leading an interagency initiative to make fundamental improvements in the way that the U.S. monitors its environment. Current monitoring programs do not provide integrated data across multiple natural resources at the various temporal and spatial scales needed to develop policies based on current scientific understanding of Earth system processes. New developments in science and technology provide new opportunities for collecting and organizing data that could greatly expand our capabilities for achieving a sustainable trajectory for the nation's future.

A critical need exists to synthesize scientific information from new and existing environmental observation technologies with comprehensive socioeconomic data to increase our understanding of the significance of interactions among resources, their linkages to variations in the natural and human environment, and their responses to multiple drivers of change. These integrated environmental assessments should identify environmental and ecosystem trends, relate these trends to their causes and consequences, and predict outcomes of alternative future socioeconomic and climatic scenarios. One of the principal recommendations from the draft National Environmental Monitoring Framework document is to increase the use of remotely sensed information obtained for detecting and evaluating environmental status and change by coordinating these analyses with ongoing in-situ monitoring and research efforts. In this effort it is essential to ensure full utilization of the data standards being developed for map and remotely sensed data by the Federal Geographic Data Committee. MTPE seeks scientific data and information from existing or to be developed commercial systems that enhances research on understanding the status and trends related to U.S. ecosystems. The emphasis in this activity is on increasing the use of remote sensing information in integrated assessments which document status and trends of multiple resources and related environmental and socioeconomic conditions in both managed and unmanaged ecosystems. The data will also be used to relate status and trends to human and natural causes and consequences, to predict future trajectories and rates of change, and to identify research needed to reduce uncertainties in current observations and projections. MTPE seeks proposals that document the spatial and spectral characteristics of all past, present, and known future remote sensing imagery for specific environments. This product could take the form of an atlas of imagery with multiple types of imagery illustrated and explained for specific locations and environments (e.g., agriculture, forests, wetland, urban, etc.). The atlas will serve to demonstrate the information which can be derived from remote sensing imagery for any future national environmental monitoring system.

4. Support the design of a prototype environmental report on trends in, and the status of, the U.S. environment.

The Vice President issued a challenge to the scientific community in September 1996, to develop an environmental report card on the status, trends, and health of the Nation's environment and natural resources. The environmental report card will require unique, new integrative indicators of the sustainability of the resource base that supports the economic and human welfare of the U.S. MTPE seeks scientific data and information which can be used in the design of an assessment of the state of the Nation's environment and natural resources. The information should address major issues like land cover and land use change, water resources, air resources, and trends in resource and ecosystem productivity. It

is expected that the ultimate environmental report card will illustrate how climatic, economic, and other forces of change relate to environmental status and trends. This design of a report card requires a variety of experimental products for assessment by scientists, policy makers, and members of the public. Emphasis is placed on the development of sustainability indicators which are easily understood by a broad audience.

5. Improve methods for the sustainable management of farmlands, forests, rangelands, and coastal marine resources.

MTPE seeks scientific information to enhance research on new and improved methods for the sustainable management of natural resources. The primary focus of the research is in two areas: (1) Reducing inputs of energy and materials to managed environments while maintaining or increasing net ecosystem productivity (e.g., high precision agriculture). (2) Early detection and characterization of stress on a managed ecosystem, which could reduce net ecosystem productivity if the stress were not removed (e.g., overgrazing of croplands, ozone stress on crops, droughts, etc.). This information should provide the basis for new insights and knowledge into the sustainable management of natural resources, and not duplicate methods and practices already available through the commercial sector. The data provider must clearly specify how the products provided contribute to the above mentioned goals of increasing the efficiency of natural resource management prances. Data products should uniquely improve spatial and temporal sampling of the environment, or combine in situ and existing remote sensing data using innovative data fusion techniques.

SCIENCE AREA: Seasonal-to-Interannual Climate Variability and Prediction

MTPE has defined a focused research effort to observe, understand, and predict weather and climate variations that occur on time scales of seasons to a year. Variations in the upper ocean circulation and sea surface temperatures, sea ice, atmospheric circulation including the hydrologic cycle, atmospheric turbidity, and land surface conditions are hypothesized to be mutually interactive and to generate significant weather and climate variability. Scientists associated with the MTPE and USGCRP programs are determining which elements of this variability are predictable if relevant initial and boundary conditions are sufficiently well known. Such an improved understanding has potentially large socioeconomic benefit. The following scientific information is required to complement and supplement the current research effort on seasonal-to-interannual climate variability and prediction:

6. Measure globally distributed atmospheric wind profiles.

MTPE seeks direct global measurements of atmospheric wind profiles at 2 m/s or better precision. The primary purpose of the measurements is to improve capabilities for prediction. Proposals to provide wind data should include a detailed rationale for the geophysical characteristics of the data. The spatial and temporal coverage, and the accuracy and precision of the data, should be justified in terms of expected improvements in prediction of seasonal-to- interannual climate variability. The data provided should be in a format suitable for incorporation into the NASA and NOAA data assimilation models.

7. Provide measurements from Global Positioning System (GPS) satellites for weather and climate prediction.

MTPE seeks measurements of atmospheric variables obtained by GPS on low-Earth orbiting satellites. The data will be used to specifically test applications to weather and climate forecasting. The data should be derived from a satellite constellation capable of global sampling in a manner appropriate to a rigorous test of whether the measurements from GPS improve forecasting skill. The data stream must be provided in a form appropriate for assimilation into current state-of-the-art weather forecasting models.

SCIENCE AREA: Natural Hazards Research and Applications

Thousands of human lives and billions of dollars are lost each year to natural disasters. While natural hazards are inevitable manifestations of Earth processes, they need not inevitably result in disasters.

NASA can assist society in reducing loss of life, casualties and property and reducing social and economic disruptions from future natural disasters. Through the development of technologies designed to observe and understand the Earth the Agency possesses a remarkable inventory of tools which can be effectively developed and applied to understanding natural hazards, characterizing natural disasters, and monitoring conditions that may lead to such events.

8. Improve methods and understanding of how best to characterize and mitigate the consequences of natural hazards for both managed and natural ecosystems.

MTPE seeks scientific data products which enhance research on the consequences of natural hazards for the sustainability of natural resources and economic development. This area of research is focused primarily on scientific issues related to the long-term consequences and management of natural hazards, and not on crisis management. For example, how can remote sensing data be integrated with demographic, socioeconomic, and in situ environmental data to improve assessments of the sensitivity and vulnerability of an area or region to extreme weather events, earthquakes, volcanic eruptions, and other natural hazards? An understanding of the environmental, social, and economic factors that render individuals, communities, and economic sectors of the U.S. more or less vulnerable to weather and climatic fluctuations is especially critical for developing strategies for sustainable economic progress. In this area MTPE also seeks scientific data which will enhance research on and understanding of the sensitivity and vulnerability of human activities to seasonal-to-interannual climate variability. Scientific information is most needed for areas and regions at greatest risk. MTPE also has a special interest in unique, new sources of high resolution remotely sensed data which can be evaluated in pilot studies related to natural hazards research. The data provider must clearly specify how the products provided will contribute to research on new and improved capabilities for characterizing and mitigating the consequences of natural hazards.

SCIENCE AREA: Long-Term Climate: Natural Variability and Change Research

Long term climate variability encompasses changes of regional-to-global scale climate, both natural and human induced, that occur over periods longer than a few years. NASA's objective is to make key contributions to a wider interdisciplinary effort involving other U.S. agencies and institutions, as well as other countries. This larger effort addresses the broad scientific agenda of the U.S. Global Change Research Program (USGCRP) at the national level, and the World Climate Research Program (WCRP), the International Geosphere-Biosphere Program (IGBP) and the Intergovernmental Panel on Climate Change (IPCC) at the international level.

Accordingly, NASA Mission to Planet Earth (MTPE) research objectives associated with the climate issue require long-term data sets that:

(a) Characterize and document long-term climate variability and trends through systematic global observations of the climate system and its external forcing;

(b) Understand the nature of key climate-forming and regulating parameters, and to identify the causal factors of observed climate variations and feedback processes that govern the response of the climate system; and

(c) Assess the predictable aspects of long-term climate variability and changes, including regional impacts, through the combined application of observation and global models.

9. Test the utility of new measurements that meet the continuity requirements of the EOS science team

The following table lists measurements and associated instruments for the current EOS science missions. The information based on EOS Level 1 requirements and other MTPE studies.

References:

EOS Program Office, Earth Observing System (EOS) Program - Level 1 Requirements, NASA Headquarters, 10 December 1991.

EOS Project Office, Execution Phase Project Plan for Earth Observing System (EOS), GSFC 170-01-01, NASA Goddard Space Flight Center, September 1993.

EOS Measurement Sets

Measurement	Instruments	Satellites
Cloud Properties (amount, optical	MODIS, GLAS, AMSR, MISR, AIRS, ASTER,	EOS AM-1, EOS PM-1, EOS AM-2, EOS Laser ALT-1, Meteor 3M-1, ISSA, ADEOS

properties, height)	EOSP, SAGE III	II, FOO/SAGE III
Radiative Energy Fluxes (top of atmosphere, surface)	CERES, ACRIM, MODIS, GLAS, MISR, AIRS, ASTER, SAGE III	EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2, EOS ACRIMSAT, EOS Laser ALT-1, ISSA, Meteor 3M-1, FOO/SAGE III, TRMM
Precipitation	AMSR	ADEOS II
Tropospheric Chemistry (ozone, precursor gases)	TES, MOPITT, SAGE III, MLS, HIRDLS, LIS	Meteor 3M-1, EOS CHEM-1, TRMM, FOO/SAGE III, EOS AM-1, EOS CHEM-1
Stratospheric Chemistry (ozone, CIO, BrO, OH, trace gasses)	MLS, HIRDLS, SAGE III, ODUS, TES	EOS CHEM-1, FOO/SAGE III, Meteor 3M-1
Aerosol Properties (stratospheric, tropospheric)	SAGE III, HIRDLS, MODIS, MISR, EOSP,GLAS	Meteor 3M-1, FOO/SAGE III, EOS CHEM-1,EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2, EOS Laser ALT-1
Atmospheric Temperature	AIRS/AMSU, MLS, HIRDLS, TES, MODIS	EOS PM-1, EOS PM-2, NOAA-K, NOAA-L, NOAA-N, EOS CHEM-1, EOS AM-1, EOS AM-2, EOS CHEM-1
Atmospheric Humidity	AIRS/AMSU/HSB, MLS, SAGE III, HIRDLS, DFA/MR, MODIS, TES	EOS PM-1, EOS PM-2, NOAA-K, NOAA-L, NOAA-N, Meteor 3M-1, FOO/SAGE III, EOS CHEM-1, EOS AM-1, EOS AM-2, Radar ALT-2, Jason-1
Lightning (events, area, flash structure)	LIS	TRMM
Total Solar Irradiance	ACRIM	EOS ACRIMSAT
Ultraviolet Spectral Irradiance	SOLSTICE	FOO/SOLSTICE
Land-Cover and Land-Use Change	ETM+/LATI, MODIS, ASTER, MISR	Landsat-7, EOS AM-2, EOS AM-1, EOS PM-1, EOS PM-2
Vegetation Dynamics	MODIS, MISR, AIRS, ETM+	EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2, Landsat-7
Land Surface Temperature	ASTER, MODIS, AIRS, ETM+	EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2, Landsat-7
Fire Occurrence (extent,	MODIS, ASTER, ETM+	EOS AM-1, EOS AM-2, EOS PM-1, EOS

thermal anomalies)		PM-2, Landsat-7
Volcanic Effects (frequency of occurrence, thermal anomalies, impact)	MODIS, ASTER, ETM+, MISR	EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2, Landsat-7
Land Surface Wetness	AMSR	ADEOS-II
Sea Surface Temperature	MODIS, AIRS, AMSR	EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2, ADEOS-II
Phytoplankton and Dissolved Organic Matter	MODIS	EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2
Surface Wind Fields	SeaWinds, AMSR, DFA/MR	ADEOS-II, Radar ALT-2, Jason-1
Ocean Surface Topography (height, waves, sea level)	DFA/MR	Radar ALT-2, Jason-1
Land Ice (ice sheet topography, ice sheet volume change, glacier change)	GLAS, ASTER, ETM+/LATI	EOS Laser ALT-1, EOS AM-1, Landsat-7, EOS AM-2
Sea Ice (extent, concentration, motion, temperature)	AMSR, DFA/MR, MODIS, ETM+/LATI, ASTER	ADEOS-II, EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2, Landsat-7, Radar, ALT-2, Jason-1
Snow Cover (extent, water equivalent)	MODIS, AMSR, ASTER, ETM+/LATI	ADEOS-II, EOS AM-1, EOS AM-2, EOS PM-1, EOS PM-2, Landsat-7

Appendix B

EOSDIS Data Formats

MTPE Scientific Data Buy participants are required to make their products and data services available to the broader Earth science community via the EOSDIS Core System (ECS) Advertising Service. The Advertising Service will enable users to locate data, information, and services both internal and external to EOSDIS. Participants will populate the ECS Advertising Service with appropriate information on their instrument and data products, and provide pointers to their World Wide Web (WWW) page or other client interface for search and access. Documentation on "advertising" data and services via ECS is provided in the ECS technical paper, "442 TP-001-001 External Data Provider Options," at http://edhs1.gsfc.nasa.gov.

Data and Metadata Standards

To facilitate access to MTPE data by the Earth science community, it is recommended that data products in the HDF-EOS (hierarchical data format) standard data format and that they generate and store metadata describing their data products that conforms to the intermediate level of the ECS Metadata Standard. Information on HDF-EOS and the ECS Metadata Standard is provided below. If a data provider proposes to use other methods or standards for data products and metadata, then cost savings and rationale should be provided, and the conversion of data from the chosen format(s) to HDF (for transition to long term archives) must be included in the cost proposal.

The production of data in the HDF-EOS standard data format will provide the capability to use public domain and commercial data analysis and data management tools and provide the highest level of service (e.g., subsetting, subsampling) for data sets when they are migrated to EOSDIS. The HDF-EOS Primer, HDF-EOS Specification, and HDF-EOS Application Program Interfaces may be located via the WWW at http://eos.nasa.gov/esdis/InfoArch. Software for producing HDF-EOS data, serving HDF-EOS data on the WWW, and visualizing HDF-EOS data is also referenced at this Web page.

Adherence to the intermediate level of the ECS Metadata standard will result in the creation of directory, inventory and guide level information compatible with EOSDIS Version 0 data standards and facilitate future interoperability with EOSDIS Version 0 and future ECS-based versions.

The ECS "DID 311, SDPS Database Design and Database Schema Specifications for the ECS, Appendix B, Mandatory Metadata" may be located via the WWW at http://eos.nasa.gov/esdis/InfoArch. Software supporting this standard is also described at this site.

Systems and Software Available for Data Providers

In addition to software which supports the standards described in the preceding paragraphs, EOSDIS Core System software for science data archiving, production, distribution, and access will be available for reuse.

A white paper describing the available systems and software, titled "ECS Support for Federated Systems," is available via the WWW at http://edhs1.gsfc.nasa.gov. References on External Data Provider interfaces to ECS will be documented in "819-RD-001-001, ECS Application Programming Interface (API) Interface Definition Document (IDD)", which will be available on or about August 30, 1996, via the WWW at http://edhs1.gsfc.nasa.gov.

Offerors can propose to use EOSDIS software and interfaces, which will be provided at no cost, to meet these interfaces. Offerors, however, must include the cost of required software licenses and hardware in their data set or product pricing.

ATTACHMENT NO. 3 - OFFEROR REPRESENTATIONS

AND CERTIFICATIONS

1. 52.212-3 OFFEROR REPRESENTATIONS AND CERTIFICATIONS COMMERCIAL ITEMS (JUN 1996)

FAR 52.212-3, OFFEROR REPRESENTATIONS AND CERTIFICATIONS-COMMERCIAL ITEMS (FAR Clause 52.212-3) (JUN 1996), are set forth in full text below. Offeror must include a completed copy of this provision with its offer. These representations and certifications will be incorporated by reference into the resultant contract. Offeror must identify the city and state where the item is manufactured or where the work is performed.

(a) Definitions as used in this Provision:

Emerging small business means a small business concern whose size is no greater than 50 percent of the numerical size standard for the standard industrial classification code designated.

Small business concern means a concern, including its affiliates, that is independently owned and operated, not dominant in the field of operation in which it is bidding on Government contracts, and qualified as a small business under the criteria in 13 CFR Part 121 and size standards in this solicitation.

Small disadvantaged business concern means a small business concern that--

(1) Is at least 51 percent unconditionally owned by one or more individuals who are both socially and economically disadvantaged, or a publicly owned business, having at least 51 percent of its stock unconditionally owned by one or more socially and economically disadvantaged individuals, and

(2) Has its management and daily business controlled by one or more such individuals. This term also means a small business concern that is at least 51 percent unconditionally owned by an economically disadvantaged Indian tribe or Native Hawaiian organization, or a publicly owned business having at least 51 percent of its stock unconditionally owned by one or more of these entities, which has its management and daily business controlled by members of an economically disadvantaged Indian tribe or Native Hawaiian organization and which meets the requirements of 13 CFR Part 124.

Women-owned small business concern means a small business concern--

(1) Which is at least 51 percent owned by one or more women or, in the case of any publicly owned business, at least 51 per cent of the stock of which is owned by one or more women; and

(2) Whose management and daily business operations are controlled by one or more women.

Women-owned business concern means a concern which is at least 51 percent owned by one or more women; or in the case of any publicly owned business, at least 51 percent of the stock of which is owned by one or more women; and whose management and daily business operations are controlled by one or more women.

(b) Taxpayer Identification Number (TIN) (26 U.S.C. 6050M)

(1) Taxpayer Identification Number (TIN)

___ TIN: _____.

___ TIN has been applied for.

___ TIN is not required because:

___ Offeror is a nonresident alien, foreign corporation, or foreign partnership that does not have income effectively connected with the conduct of a trade or business in the U.S. and does not have an office or place of business or a fiscal paying agent in the U.S.;

___ Offeror is an agency or instrumentality of a foreign government;

___ Offeror is an agency or instrumentality of a Federal, state, or local government;

___ Other. State basis. _____

(2) Corporate Status

___ Corporation providing medical and health care services, or engaged in the billing and collecting of payments for such services;

___ Other corporate entity;

___ Not a corporate entity:

___ Sole proprietorship

___ Partnership

___ Hospital or extended care facility described in 26 CFR 501(c)(3) that is exempt from taxation under 26 CFR 501(a).

(3) Common Parent

___ Offeror is not owned or controlled by a common parent.

Name and TIN of common parent:

___Name _____.

___TIN _____.

(c) Offeror Representations

Offerors must complete the following representations when the resulting contract is to be performed inside the United States, its territories or possessions, Puerto Rico, the Trust Territory of the Pacific Islands, or the District of Columbia. Check all that apply.

(1) Small business concern. The offeror represents as part of its offer that it ( ) is, ( ) is not a small business concern.

(2) Small disadvantaged business concern. The offeror represents and certifies that it ( ) is, ( ) is not a small disadvantaged business concern.

(3) Women-owned small business concern. The offeror represents that it ( ) is, ( ) is not a women-owned small business concern.

Note: Complete paragraphs (c)(4) and (c)(5) only if this solicitation is expected to exceed the simplified acquisition threshold ($100,000).

(4) Women-owned business concern. The offeror represents that it ( ) is, ( ) is not, a women-owned business concern.

(5) Tie bid priority for labor surplus area concerns. If this is an invitation for bid, small business offerors may identify the labor surplus areas in which costs to be incurred on account of manufacturing or production (by offeror or first-tier subcontractors) amount to more than 50 percent of the contract price:

_____

(6) Small Business Size for the Small Business Competitiveness Demonstration Program and for the Targeted Industry Categories under the Small Business Competitiveness Demonstration Program. [Complete only if the offeror has certified itself to be a small business concern under the size standards for this solicitation.]

(i) (Complete only for solicitations indicated in an addendum as being set-aside for emerging small businesses in one of the four designated industry groups (DIGs)). The offeror represents as part of its offer that it ( ) is, ( ) is not an emerging small business.

(ii) (Complete only for solicitations indicated in an addendum as being for one of the targeted industry categories (TICs) or four DIGs. Offeror represents and certifies as follows:

(A) Offeror's number of employees for the past 12 months (check the Employees column if size standard stated in the solicitation is expressed in terms of number of employees); or

(B) Offeror's average annual gross revenue for the last 3 fiscal years (check the Average Annual Gross Number of Revenues column if size standard stated in the solicitation is expressed in terms of annual receipts).

Check one item:

Number of Employees	Average Annual Gross Revenues
___ 50 or fewer	_____ $1 million
___ 51-100	_____ $1,000,001 - $2 million
___ 101-250	_____ $2,000,001 - $3.5 million
___ 251-500	_____ $3,500,001 - $5 million
___ 501-750	_____ $5,000,001 - $10 million
___ 751-1,000	_____ $10,000,001 - $17 million
___ Over 1,000	_____ Over $17 million

(d) Certifications and representations required to implement provisions of Executive Order 11246

(1) Certification of non-segregated facilities

(Applies only if the contract amount is expected to exceed $10,000.) By submission of this offer, the offeror certifies that it does not and will not maintain or provide for its employees, any facilities that are segregated on the basis of race, color, religion, or national origin because of habit, local custom, or otherwise and that it does not and will not permit its employees to perform their services at any location where segregated facilities are maintained. The offeror agrees that a breach of this certification is a violation of the Equal Opportunity clause in the contract.

(2) Previous Contracts and Compliance

The offeror represents that--

(i) It ( ) has, ( ) has not, participated in a previous contract or subcontract subject either to the Equal Opportunity clause of this solicitation, the clause originally contained in Section 310 of Executive Order 10925, or the clause contained in Section 201 of Executive Order 11114; and

(ii) It ( ) has, ( ) has not, filed all required compliance reports.

(3) Affirmative Action Compliance

The offeror represents that--

(i) It ( ) has developed and has on file, ( ) has not developed and does not have on file, at each establishment, affirmative action programs required by rules and regulations of the Secretary of Labor (41 CFR Subparts 60-1 and 60-2), or

(ii) It ( ) has not previously had contracts subject to the written affirmative action programs requirement of the rules and regulations of the Secretary of Labor.

(e) Certification Regarding Payments to Influence Federal Transactions (31 U.S.C. 1352)

(Applies only if the contract is expected to exceed $100,000.) By submission of its offer, the offeror certifies to the best of its knowledge and belief that no Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress or an employee of a Member of Congress on his or her behalf in connection with the award of any resultant contract.

(f) Buy American Act--Trade Agreements--Balance of Payments Program Certificate. (Applies only if FAR clause 52.225-9 , "Buy American Act--Trade Agreement--Balance of Payments Program", is included in this solicitation.)

(1) The offeror hereby certifies that each end product, except those listed in paragraph (f)(2) of this provision, is a domestic end product (as defined in the clause entitled "Buy American Act--Trade Agreements Balance of Payments Program") and that components of unknown origin have been considered to have been mined, produced, or manufactured outside the United States, a designated country, a North American Free Trade Agreement (NAFTA) country, or a Caribbean Basin country, as defined in section 25.401 of the Federal Acquisition Regulation.

(2) Excluded End Products:

Line item No.	Country of origin
_____	_____
_____	_____

(List as necessary)

(3) Offers will be evaluated by giving certain preferences to domestic end products, designated country end products, NAFTA country end products, and Caribbean Basin country end products over other end products. In order to obtain these preferences in the evaluation of each excluded end product listed in paragraph (f)(2) of this provision, offerors must identify and certify below those excluded end products that are designated or NAFTA country

end products, or Caribbean Basin country end products. Products that are not identified and certified below will not be deemed designated country end products, NAFTA country end products, or Caribbean Basin country end products. Offerors must certify by inserting the applicable line item numbers in the following:

(i) The offeror certifies that the following supplies qualify as Designated or NAFTA country end products as those terms are defined in the clause entitled Buy American Act--Trade Agreements--Balance of Payments Program:

_____

(Insert line item numbers)

(ii) The offeror certifies that the following supplies qualify as Caribbean Basin country end products as that term is defined in the clause entitled Buy American Act--Trade Agreements--Balance of Payments Program:

_____

(Insert line item numbers)

(4) Offers will be evaluated in accordance with FAR Part 25.

(g) (1) Buy American Act--North American Free Trade Agreement Implementation Act--Balance of Payments Program.

(Applies only if FAR clause 52.225-21, Buy American Act--North American Free Trade Agreement Implementation Act--Balance of Payments Program, is included in this solicitation.)

(i) The offeror certifies that each end product being offered, except those listed in paragraph (g)(1)(ii) of this provision, is a domestic end product (as defined in the clause entitled “Buy American Act--North American Free Trade Agreement Implementation Act-Balance of Payments Program."), and that components of unknown origin have been considered to have been mined, produced, or manufactured outside the United States.

(ii) Excluded End Products:

Line item No. Country of origin

_____ _____

(List as necessary)

(iii) Offers will be evaluated by giving certain preferences to domestic end products or NAFTA country end products over other end products. In order to obtain these preferences in the evaluation of each excluded end product listed in paragraph (g)(1)(ii) of this provision, offerors must identify and certify below those excluded end products that are NAFTA country end products. Products that are not identified and certified below will not be deemed NAFTA country end products.

The offeror certifies that the following supplies qualify as "NAFTA country end products" as that term is defined in the clause entitled "Buy American Act--North American Free Trade Agreement Implementation Act--Balance of Payments Program":

_____

_____

_____

(Insert line item numbers)

(iv) Offers will be evaluated in accordance with FAR Part 25 of the Federal Acquisition Regulations. In addition, if the solicitation is for supplies for use outside of the United States, an evaluation factor of 50 percent will be applied to offers of end products that are not domestic or NAFTA country end products.

(2) *Alternate I*. If Alternate I to the clause at 52.225-21 is included in this solicitation, substitute the following paragraph (g)(1)(iii) for paragraph (g)(1)(iii) of this provision:

(g)(1)(iii)(iii) Offers will be evaluated by giving certain preferences to domestic end products or Canadian end products over other end products. In order to obtain these preferences in the evaluation of each excluded end product listed in paragraph (b) of this provision, offerors must identify below those excluded end products that are Canadian end products. Products that are not identified below will not be deemed Canadian end products.

The following supplies qualify as Canadian end products as that term is defined in the clause entitled "Buy American Act--North American Free Trade Agreement Implementation Act--Balance of Payments Program":

_____

(Insert line item numbers)

(h) Certification Regarding Debarment, Suspension or Ineligibility for Award (Executive Order 12549)

The offeror certifies, to the best of its knowledge and belief, that--

(1) The offeror and/or any of its principals ( ) are, ( ) are not presently debarred, suspended, proposed for debarment, or declared ineligible for the award of contracts by any Federal agency, and

(2) ( ) Have, ( ) have not, within a three-year period preceding this offer, been convicted of or had a civil judgment rendered against them for: commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a Federal, state or local government contract or subcontract; violation of Federal or state antitrust statutes relating to the submission of offers; or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, tax evasion, or receiving stolen property; and ( ) are, ( ) are not presently indicted for, or otherwise criminally or civilly charged by a Government entity with, commission of any of these offenses.

ADDENDUM NO. 1- INSTRUCTIONS TO OFFERORS

1. Instructions to Offerors - Commercial Items (FAR Clause 52.212-1) (OCT 1995)

The following provision is incorporated as an addendum to item (c) "Period for acceptance of offers" of FAR Clause 52.212-1: The offeror agrees to hold the price in its offer firm for 60 calendar days from the date specified for receipt of offer. Also note that in accordance with FAR 52.212-1(e), offerors are encouraged to submit multiple offers presenting alternative terms and conditions or commercial items satisfying the requirements of this solicitation. Each offer submitted will be evaluated separately

2. Data Distribution

The offers submitted in response to this RFO must identify clearly the scientific area and questions being addressed and must provide a clear explanation of the relevance of the proposed effort in the context of the identified research area and questions. The data sets provided in response to this solicitation should be in a format conducive to low-cost distribution to a broad community of users and compatible with the EOS Data and Information System (EOSDIS). The formatting requirements for EOSDIS are given in Appendix B. All information should be georeferenced and presented in a geospatial format in accordance with guidelines established by the Federal Geographic Data Committee. Data sets must be provided with complete metadata that can be used as a catalog for potential users. The full underlying data from which any products are derived must be provided to NASA in a format suitable for archival in the EOSDIS. Materials provided in CD-ROM format must be ISO-9660 compatible and readable on PC, Macintosh, and UNIX systems.

The offeror may, at its discretion, propose alternative data distribution methods for consideration. All alternatives should be included in the price quotation for the data set or product purchases.

3. Intellectual Property Rights: Data and Data Products

As part of the phase I offers, the data provider will discuss the data rights provisions of the associated data set or product being offered. This solicitation is consistent with NASA's recently published MTPE Commercial Strategy as outlined in the following sections.

3.1 Data Sets

Licensing and other intellectual property rights to data purchased by the U.S. Government under this RFO will be established subject to mutually agreeable terms with the data vendors. It is NASA's desire to purchase data sets under the following conditions:

- In general, NASA will reserve the right to distribute data to researchers affiliated with MTPE through grants or other formal mechanisms, and to researchers in the international community with whom NASA has data exchange arrangements.

- NASA will not commercially exploit property in which the U.S. Government holds a license.

- MTPE data products derived from purchased data sets will have no restrictions on access by and distribution to the science community outside the MTPE program.

Data providers seeking alternative approaches to data rights are encouraged to define these alternatives in their proposals.

3.2 Data Provider

Use by NASA of data products purchased by or licensed to the U.S. Government under this RFO will be established subject to mutually agreeable terms with the data product provider. It is NASA's desire to purchase data sets under the following conditions:

- In general, NASA will reserve the right to distribute data products to researchers affiliated with MTPE through grants or other formal documented mechanisms, and to researchers in the international community with whom NASA has data exchange arrangements.

- NASA will respect copyright protection associated with data products and will not commercially exploit property in which the U.S. Government holds a license.

- If the data products embody other commercial data, products, software, or other commercial services, the offeror must indicate the mechanism by which their use transfers to NASA.

Data providers seeking alternative approaches to data products are encouraged to define these alternatives in their proposals

4. Validation Plan

For each proposal, the data provider must submit a validation plan for its specific data set(s) or product(s). Under phase I of the data purchase RFO process, the validation plan for each data set will be evaluated. Evaluation will be based in part upon the techniques outlined in the offer as compared with state-of-the-practice and state-of-the-art validation techniques.

The validation plan will be developed by the data provider and must address the manner in which data sets will be evaluated by the data provider to maintain advertised specifications and quality. The plan will contain the projected data characteristics and performance specifications. Validation parameters will be an important element of the offer for providing data and data products. All validation plans submitted will be evaluated by Stennis Space Center (SSC) with support from the data provider and the MTPE science team. For land use/land cover type data sets, data providers will be allowed access to the SSC validation site and verification network for testing their data sets. Use of the SSC validation site must comply with the guidelines set forth in the National Verification Site Initiative, Stennis Space Center.

It is essential that data quality be maintained throughout the life of the contract. Those providing data under the second phase of the data purchase will be required to furnish a Quality Assurance/Quality Control plan detailing how data quality will be maintained throughout the life of the contract. In addition, Stennis Space Center will re-validate the phase II data sets or products against the data-provider-developed validation plan to benchmark the quality of the data. If the data or data products are found to be of insufficient quality or do not meet the specifications as outlined in the quality assurance plan, that

data or data product will be deemed unacceptable under the contract and will not be accepted or paid for by NASA.

5. Proposal Format

The proposals offered in response to this RFO will be submitted according to the format described below. Proposals (including appendices) should not exceed 20 pages for phase I, should be in 12-point type, and should be submitted to the NASA/SSC Procurement Office. Proposals must be signed by an official of the company and/or corporation authorized to certify management and financial aspects of the proposed contract. Proposals should be sent to the following address:

MTPE Scientific Data Buy Proposal
C/O: Rebecca Dubuisson /DA30 - Contracting Officer
NASA John C. Stennis Space Center
Bldg. 1100, Room 255L
SSC, MS 39529-6000

6. Proposal Content

All phase I proposals shall contain the following information

1) A complete description of the proposed data set and the science research theme(s) it will address

2) A price quotation for prototypical data sets for the evaluation phase of the process

3) A complete data validation plan

4) Proposed arrangements for data rights

5) A data delivery plan

6) Point(s) of contact

7) An estimate of the price of the final product including both the price per data set or per time period and, if applicable, the minimum required purchase value.

Table 2 describes the format for phase I of the proposal.

Table 2. Phase I Proposal Format.

Item	Content	RFO Section	Suggested Page Limit
1	Cover Letter	n/a	n/a
2	Title Page	n/a	1
3	Executive Summary	n/a	1
4	Table of Contents	n/a	n/a
5	Introduction	n/a	1
6	Science Research Theme Addressed	5.0	5
7	Data Description	5.0	5
8	Data Validation Plan	7.0	2
9	Data Distribution Plan	11.0	1
10	Prototypical Data Prices and Estimated Data Prices	12.0	1
11	Data Policy/Rights	8.0	1
12	Contact Personnel	n/a	1

The data provider should follow the general format specified above. The suggested page limits are only estimates based upon the amount of space certain portions of the proposal may require. If the data provider deems that less or more space is necessary for a portion of the proposal, the data provider may develop the content as required, as long as the entire proposal does not exceed the 20-page limit for a single data set or product offering. As indicated in the RFO, multiple data sets or products may be offered under one proposal. Additional pages for each offered product may be used as long the suggested page limit is not exceeded for each required section. The offeror can duplicate sections 6, 7, 8, 9, l0 and ll, as necessary to describe the products offered.

ADDENDUM NO. 2 - ADDITIONAL FAR/NFS PROVISIONS

A firm fixed-price commercial item contract will be awarded in accordance with Federal Acquisition Regulations (FAR) Subpart 12, as supplemented by the NASA Midrange Pilot Test Program approved by the Office of Federal Procurement Policy on April 16, 1993.

1. DESIRED AND REQUIRED TIME OF DELIVERY (52.211-9) (JUL 1995)

The Government desires delivery to be made according to the following delivery schedule:

DESIRED DELIVERY SCHEDULE		
ITEM NO.	QUANTITY	WITHIN CALENDAR DAYS AFTER DATE OF CONTRACT AWARD
1		180

If the offeror is unable to meet the desired delivery schedule, it may, without prejudicing evaluation of its offer, propose a delivery schedule below. However, the offeror's delivery proposed delivery schedule must not extend the delivery period beyond the time for delivery in the Government's required delivery schedule as follows:

REQUIRED DELIVERY SCHEDULE		
ITEM NO.	QUANTITY	WITHIN CALENDAR DAYS AFTER DATE OF CONTRACT AWARD
1		180

Offerors that propose delivery of a quantity under such terms or conditions that delivery will not clearly fall within the applicable required delivery period specified above, may be rejected. If the offeror proposes no other delivery schedule, the desired delivery schedule above will apply.

OFFEROR'S PROPOSED DELIVERY SCHEDULE		
ITEM NO.	QUANTITY	WITHIN CALENDAR DAYS AFTER DATE OF CONTRACT AWARD
1		

2. MANDATORY INFORMATION FOR ELECTRONIC FUNDS TRANSFER PAYMENT 52.232-33 (AUG 1996)

(a) Method of payment. Payments by the Government under this contract, including invoice and contract financing payments, may be made by check or electronic funds transfer (EFT) at the option of the Government. If payment is made by EFT, the Government may, at its option, also forward the associated payment information by electronic transfer. As used in this clause, the term "EFT" refers to the funds transfer and may also include the information transfer.

(b) Mandatory submission of Contractor's EFT information.

(1) The Contractor is required, as a condition to any payment under this contract, to provide the Government with the information required to make payment by EFT as described in paragraph (d) of this clause, unless the payment office determines that submission of the information is not required. However, until January 1, 1999, in the event the Contractor certifies in writing to the payment office that the Contractor does not have an account with a financial institution or an authorized payment agent, payment shall be made by other than EFT. For any payments to be made after January 1, 1999, the Contractor shall provide EFT information as described in paragraph (d) of this clause.

(2) If the Contractor provides EFT information applicable to multiple contracts, the Contractor shall specifically state the applicability of this EFT information in terms acceptable to the payment office.

(c) Contractor's EFT information. Prior to submission of the first request for payment (whether for invoice or contract financing payment) under this contract, the Contractor shall provide the information required to make contract payment by EFT, as described in paragraph (d) of this clause, directly to the Government payment office named in this contract. If more than one payment office is named for the contract, the Contractor shall provide a separate notice to each office. In the event that the EFT information changes, the Contractor shall be responsible for providing the changed information to the designated payment office(s).

(d) Required EFT information. The Government may make payment by EFT through either an Automated Clearing House (ACH) subject to the banking laws of the

United States or the Federal Reserve Wire Transfer System at the Government's option. The Contractor shall provide the following information for both methods in a form acceptable to the designated payment office. The Contractor may supply this data for this or multiple contracts (see paragraph (b) of this clause).

(1) The contract number to which this notice applies.

(2) The Contractor's name and remittance address, as stated in the contract, and account number at the Contractor's financial agent.

(3) The signature (manual or electronic, as appropriate), title, and telephone number of the Contractor official authorized to provide this information.

(4) For ACH payments only:

(i) Name, address, and 9-digit Routing Transit Number of the Contractor's financial agent.

(ii) Contractor's account number and the type of account (checking, saving, or lockbox).

(5) For Federal Reserve Wire Transfer System payments only:

(i) Name, address, telegraphic abbreviation, and the 9-digit Routing Transit Number for the Contractor's financial agent.

(ii) If the Contractor's financial agent is not directly on-line to the Federal Reserve Wire Transfer System and, therefore, not the receiver of the wire transfer payment, the Contractor shall also provide the name, address, and 9-digit Routing Transit Number of the correspondent financial institution receiving the wire transfer payment.

(e) Suspension of payment.

(1) Notwithstanding the provisions of any other clause of this contract, the Government is not required to make any payment under this contract until after receipt, by the designated payment office, of the correct EFT payment information from the Contractor or a certificate submitted in accordance with paragraph (b) of this clause. Until receipt of the correct EFT information, any invoice or contract financing request shall be deemed not to be a valid invoice or contract financing request as defined in the Prompt Payment clause of this contract.

(2) If the EFT information changes after submission of correct EFT information, the Government shall begin using the changed EFT information no later than the 30th day after its receipt to the extent payment is made by EFT. However, the Contractor may request that no further payments be made until the changed EFT information is implemented by the payment office. If such suspension would result in a late payment under the Prompt Payment clause of this contract, the Contractor's request for suspension shall extend the due date for payment by the number of days of the suspension.

(f) Contractor EFT arrangements. The Contractor shall designate a single financial agent capable of receiving and processing the electronic funds transfer using the

EFT methods described in paragraph (d) of this clause. The Contractor shall pay all fees and charges for receipt and processing of transfers.

(g) Liability for uncompleted or erroneous transfers.

(1) If an uncompleted or erroneous transfer occurs because the Government failed to use the Contractor-provided EFT information in the correct manner, the Government remains responsible for (i) making a correct payment, (ii) paying any prompt payment penalty due, and (iii) recovering any erroneously directed funds.

(2) If an uncompleted or erroneous transfer occurs because Contractor-provided EFT information was incorrect at the time of Government release of the EFT payment transaction instruction to the Federal Reserve System, and--

(i) If the funds are no longer under the control of the payment office, the Government is deemed to have made payment and the Contractor is responsible for recovery of any erroneously directed funds; or

(ii) If the funds remain under the control of the payment office, the Government retains the right to either make payment by mail or suspend the payment in accordance with paragraph (e) of this clause.

(h) EFT and prompt payment.

(1) A payment shall be deemed to have been made in a timely manner in accordance with the Prompt Payment clause of this contract if, in the EFT payment transaction instruction given to the Federal Reserve System, the date specified for settlement of the payment is on or before the prompt payment due date, provided the specified payment date is a valid date under the rules of the Federal Reserve System.

(2) When payment cannot be made by EFT because of incorrect EFT information provided by the Contractor, no interest penalty is due after the date of the uncompleted or erroneous payment transaction, provided that notice of the defective EFT information is issued to the Contractor within 7 days after the Government is notified of the defective EFT information.

(i) EFT and assignment of claims. If the Contractor assigns the proceeds of this contract as provided for in the Assignment of Claims clause of this contract, the assignee shall provide the assignee EFT information required by paragraph (d) of this clause. In all respects, the requirements of this clause shall apply to the assignee as if it were the Contractor. EFT information which shows the ultimate recipient of the transfer to be other than the Contractor, in the absence of a proper assignment of claims acceptable to the Government, is incorrect EFT information within the meaning of paragraph (e) of this clause.

(j) Payment office discretion. If the Contractor does not wish to receive payment by EFT methods for one or more payments, the Contractor may submit a request to the designated payment office to refrain from requiring EFT information or using the EFT payment method. The decision to grant the request is solely that of the Government.

(k) Change of EFT information by financial agent. The Contractor agrees that the Contractor's financial agent may notify the Government of a change to the routing transit number, Contractor account number, or account type. The Government shall use the changed data in accordance with paragraph (e)(2) of this clause. The Contractor agrees that the information provided by the agent is deemed to be correct information as if it were provided by the Contractor. The Contractor agrees that the agent's notice of changed EFT data is deemed to be a request by the Contractor in accordance with paragraph (e)(2) that no further payments be made until the changed EFT information is implemented by the payment office.

ADDENDUM NO. 3 - EVALUATION PROCESS

COMPETITIVE NEGOTIATED PROCUREMENT USING QUALITATIVE CRITERIA

The scientific data buy procurement is part of NASA's intent to augment and where practical replace traditional contracting methodologies by instituting new ways of doing business that reflect a faster, better, cheaper way of carrying out its mission. Thus, each response will be examined for the innovations which are critical to obtaining the data sets more efficiently. Innovation in both the technical and procurement processes are considered an important factor and can be demonstrated throughout the proposal in such direct elements as data acquisition and delivery and in such indirect elements as data rights.

This procurement will be conducted utilizing Best Value Selection (BVS), which seeks to select an offer based on the best combination of price and qualitative merit of the offers submitted and reduce the administrative burden on the offerors and the Government. BVS predefines the value characteristics which will serve as the discriminators among offers.

BVS evaluation is based on the premise that, if all offers are of approximately equal qualitative merit, award will be made to the offeror(s) with the lowest evaluated price. However, the Government will consider awarding to an offeror(s) with higher qualitative merit if the difference in price is commensurate with the added value. Conversely, the Government will consider making award to an offeror whose offer has lower qualitative merit if the price differential between it and other offers warrants doing so.

The following value characteristics establish what the Government considers to be valuable in an offer. These value characteristics are performance based and permit selection of the offer which provides better results for a reasonable marginal increase in price. Price and technical will be considered equal in importance and will not be assigned weights. On those value characteristics the offeror chooses to provide, adequate information should be submitted to permit proper evaluation. The value characteristics are:

- The degree to which the offered data meets the scientific requirements of the solicitation; and

- The degree to which the offered data meets the business and performance requirements of the solicitation, such as, the basis for the price quotation, arrangements for property rights, and consistency of the overall offer with the goals of the RFO.

The Government will evaluate offers in the following general steps:

(a) An initial evaluation will be performed to determine if all required information has been provided and the offeror has made a reasonable attempt to present an acceptable offer. Offerors may be contacted, by the Contracting Officer, only for clarification purposes during the initial evaluation. Offerors determined

not to be acceptable shall be notified of their rejection and the reasons therefor and excluded from further consideration.

(b) All acceptable offers will be evaluated against the requirements of the RFO, including the value characteristics listed above. Two groups of reviewers, a Science Evaluation Group and a Price and Performance Group, will conduct the reviews, as follows:

(1) Science Characteristics

Each response to the RFO will be evaluated on the submittal's demonstrated understanding of and response to the science research theme or EOS measurement it is attempting to address. Some important characteristics of the science evaluation include:

(i) Is the necessary information present to perform a comprehensive evaluation.

(ii) The relevance of the proposed data set or product to the MTPE research themes or EOS measurement sets identified in this RFO.

(iii) The approach to providing a data set or product that addresses the MTPE research theme or EOS measurement set.

(iv) Best science value of the approach to other approaches of providing data sets or products.

(2) Price and Performance Characteristics

Each response to the RFO will be evaluated on the submittal's demonstrated understanding of and response to the economic factors that impact the cost effectiveness of the information package. For example, NASA realizes that licensing and other arrangements for intellectual property protection are inextricably related to pricing, use and fair market value of the data and data products. These characteristics include:

(i) Price efficiency factors related to the reasonableness of the price quotation. Is the basis clearly explained for the proposed price to NASA of the data or data product? This basis may include such factors as the extent to which the vendor accepts a major portion of the up-front financial risk and special requirements of the identified science community, including data types, delivery characteristics and archiving, multi-site licensing, and other factors.

(ii) The arrangements under which the offeror intends to handle non-proprietary use of space acquired data; the proprietary use of data for scientific evaluation and reporting; and any restrictions imposed on the uses for reporting and publication.

(iii) The past performance and the ability of the vendor to supply the data/data products as proposed, that is, the credibility of the vendor and the offer. Considerations influencing this factor include past performance of the company on other projects, any current backlog

and responses to similar orders. In general, an important consideration is the overall reputation of the company as a credible supplier and the risk NASA must assume as the procurer.

Appendix B. Customer Feedback Letter

Customer Feedback Letter

RETURN TO: Troy Frisbie
Scientific Data Purchase Project Manager
Earth Science Applications Directorate
National Aeronautics and Space Administration
Stennis Space Center, MS 39529

TO: NASA Earth Science Enterprise Scientific Data Purchase data recipients

NASA's Earth Science Applications Directorate at Stennis Space Center, Mississippi, is dedicated to enhancing and improving current and future Earth Science Enterprise Scientific Data Purchase (SDP) activity. In an effort to assure the Data Purchase project is meeting the needs and expectations of the data recipients in the scientific community, we would appreciate your taking the time to answer the following questions:

Data Recipient's Name _____ Date _____

Data Recipient's Organization/Affiliation_____

SDP Task No. _____ or Order No._____

Date Data Shipped _____

Type of Data: ☐ Positive Systems ☐ EarthWatch ☐ EarthSat ☐ Space Imaging

QUALITY ASSESSMENT

1. Please rate from 1 (data seriously flawed) to 10 (data exceptional) your impression of the quality of the data received.

Rating _____

Comment:

2. Please rate from 1 (service non-responsive) to 10 (service exceptional) your experience with the Scientific Data Purchase process from data request through data delivery.

Rating _____

Comment:

3. Please rate from 1 (service non-responsive) to 10 (service exceptional) your experience with the Scientific Data Purchase data vendors (Earth Watch, Space Imaging, Positive Systems, EarthSat) as applicable.

Rating _____

Comment:

PROGRAM ASSESSMENT

4. Please rate from 1 (data not useful) to 10 (data highly useful) your impression of the usefulness of the data in your research/application.

Rating _____

Comment:

5. Please rate from 1 (adverse effect) to 10 (no effect) any limitations that the Data Rights agreement had on the utility of the data or on your ability to accomplish research objectives.

Rating _____

Comment:

6. Please let us know if there have been any publications as a result of research using the data.

Publications:

7. For us to better report to our sponsors, please describe any benefits to the U.S. taxpayers derived from your use of the data.

8. Do you encourage continuation of the current Scientific Data Purchase effort into the future?

9. Do you encourage the Scientific Data Purchase project to pursue new sources of commercial data, and if so, what data products?

10. Please provide any other general thoughts or suggestions as to how we can improve the project.

Thank you for taking the time to complete this questionnaire. Feel free to contact me anytime at 228-688-1989 if you have any questions or comments regarding the NASA ESE Scientific Data Purchase project.

Sincerely,

Troy Frisbie
Scientific Data Purchase Project Manager
Earth Science Applications Directorate
National Aeronautics and Space Administration
Stennis Space Center, MS 39529

Appendix C. E-mail Survey

E-mail disseminated to all SDP users who received data:

Dear Scientific Data Purchase Participant:

Dr. Lauren Underwood is compiling a summary of the impact of the commercial data distributed by NASA through the Scientific Data Purchase (SDP) project. This summary will be forwarded to NASA Headquarters, and used to evaluate the utility of commercial data in the science and applications projects sponsored by the Earth Science Enterprise. As a recipient of data from SDP, it would be of great assistance to NASA, and a potential benefit to the remote sensing community, if you would take a few moments and supply the information requested below.

Our records show that you received the following data set(s) from the SDP:
(**script insert*-- order#/task#, data type, location, data product, total # of scenes, date data was sent)

For each data set, please supply:

- A brief summary of the impact the SDP had on your research (e.g. comments regarding SDP data's effectiveness, the role SDP data had in enhancing your research, the role SDP data may play in future research/application projects)
- A list of publications (including abstracts, presentations, and pending work) that have incorporated the use of SDP data (if possible, please send reprint copies as well) and/or a list of data products or applications derived from SDP data
- Please indicate any issues (technical, administrative, other) that precluded effective use of the data you received
- Please express your interest in attending/presenting your SDP data results at a future workshop focusing on the results of the SDP

Your response to this message is requested by March 11, 2002, and August 2, 2002, respectively. Please forward any and all correspondences/questions to Lauren W. Underwood, Ph.D., LMSO, Building 1105 Stennis Space Center, MS 39529, Ph: 228-688-2096, Email: Lauren.Underwood@ssc.nasa.gov.

Thank you for taking the time to provide us with this important information.

Sincerely,

(Signature on file)

Troy E. Frisbie
Scientific Data Purchase Project Manager
NASA Earth Science Applications Directorate
Stennis Space Center, MS
Ph: 228-688-1989
Fax: 228-688-7455
Email: Troy.Frisbie@ssc.nasa.gov

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